DESIGN REVIEW

for

REMEDIAL ACTION

at

C.P.S./MADISON SITES

for

New Jersey Department

of Environmental Protection

by

CH2M HILL

August 1984

DESIGN REVIEW REPORT

for
C.P.S./MADISON SITES
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for
NEW JERSEY DEPARTMENT
OF ENVIRONMENTAL PROTECTION

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Section 1
SUMMARY AND CONCLUSIONS

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This Design Review Report completes CH2M HILL's Task 1 efforts for the State of New Jersey Department of Environmental Protection (NJ DEP) toward completion of contact documents and construction management services for remedial action implementation at C.P.S. Chemical Company/ Madison Industries, Inc. (C.P.S./Madison). The purpose of this task was to become familiar with the site conditions, to identify any significant data gaps, and to review and evaluate the remedial activities proposed in the feasibility study prepared for the New Jersey Superior Court.

The preliminary design of the remedial activities prepared by the NJ DEP were divided into two contracts as follows; 1) The slurry containment wall and appurtenances, including maintenance wells within the area enclosed by the wall and decontamination wells outside of the wall; and 2) the relocation of Pricketts Brook.

The first contract was divided in this report for the purpose of evaluating individual components of the remedial design. These components are addressed in separate sections as follows:

Section 3: Relocation of Pricketts Brook
Section 4: Slurry Containment Wall
Section 5: Groundwater Recovery Wells.

Based on this review, CH2M HILL has identified additional investigations needed to increase the potential for the proposed remedial actions to meet the objectives of the Court. CH2M HILL has developed suggested modifications to the remedial design which we believe will improve the performance of the remedial actions. These suggested modifications are based on our interpretation of the available data and may be revised subject to the additional investigations proposed for Task 2 and additional data developed by others.

The proposed relocation of Pricketts Brook and the proposed locations for maintenance wells inside of the area enclosed by the slurry containment wall and decontamination wells outside of the enclosed area are considered constructable and beneficial toward meeting the remedial objectives established for the C.P.S./Madison site. The slurry containment wall should be modified to improve contructability and effectiveness. These individual remedial design components are discussed further in their respective sections.

Proposed modifications to the NJ DEP preliminary design plans include an extension of the slurry containment wall to the south and southwest, alternate trench backfill material along Old Waterworks Road, installation of three float-controlled, 120-gallon per minute maintenance wells inside the slurry containment wall, and modifying the route for the relocation of Pricketts Brook.

The recommended location for the slurry containment wall would enclose the entire area of known contamination, thereby eliminating the need for decontamination wells outside of the slurry containment wall. The use of alternate backfill materials would reduce constructability problems. The recommended relocation of Pricketts Brook would minimize excavation quantities, would reduce construction related health and safety hazards, would reduce the impact to the surrounding environment, and is necessary to accommodate the recommended location of the slurry containment wall. The locations of these facilities are shown in Figure 1.1. The NJ DEP preliminary design plans are shown for comparison.

Limited special services and investigations needed to improve the reliability of design parameters were identified during Task 1. These are listed along with order-of-magnitude costs in Table 1.1.

The area of treatment and disposal of the recovered contaminated groundwater is outside of the scope of Task 1 and was therefore not addressed in this report. As such operation and maintenance costs were not included in the cost presentations since they are highly dependent on the method of treatment and disposal.

The aquifers in the area are being drawn upon rather heavily and every effort should be made to deprive the users of the aquifers of as little groundwater as possible. The elimination of the decontamination wells through enlarging the containment area will reduce the draw from the aquifer. It is also possible to treat the recovered groundwater from the maintenance wells inside the containment area and to land apply it to further reduce the loss of groundwater available in the aquifers. Land applying the treated groundwater would also leave more sewer capacity available for other uses, and eliminate the water conveyance system from the site to the sewer authority.

It is proposed that bench scale testing be done on the leachate (contaminated groundwater) along with a literature search to determine the best method of treatment and expected removals of contaminants from the groundwater. At the same time land application of the treated water should be studied. These tasks should be done concurrently with or as part of Task 2.

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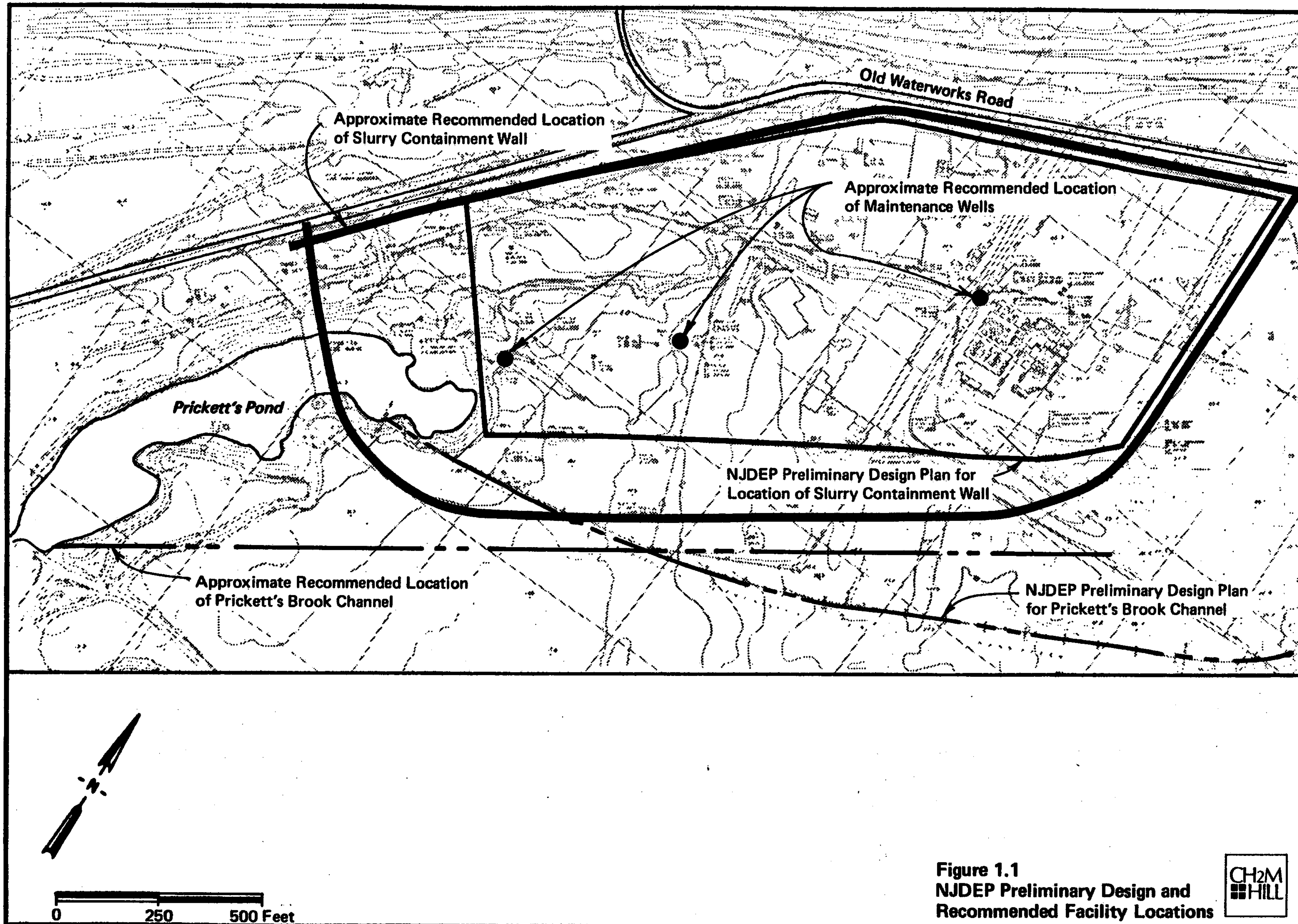

Figure 1.1
NJDEP Preliminary Design and Recommended Facility Locations

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Table 1.1
PROPOSED TASK 2 SERVICES AND
ORDER-OF-MAGNITUDE COSTS

Activity	Order-of-Magnitude Cost
1. Rainfall-Runoff Computer Simulation	$ 1,000
2. Flood Routing Computer Simulation	$ 1,250
3. Topographic Survey along Modified Alignments of Pricketts Brook and the Slurry Wall	$ 2,500
4. Regional Groundwater Flow Modeling of the Old Bridge Sand Aquifer	$30,000
5. Detailed Groundwater Flow/Contaminant Transport Modeling of Slurry Containment Wall-Groundwater Recovery Well Options	$40,000
6. Borehole Investigations Including Two Stratigraphic Confirmation Boreholes, Nine Groundwater Monitoring Wells and Two Pump Test Wells	$96,000
7. Ten Complete Priority Pollutant Analyses of Groundwater Samples	$11,200

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Section 2
INTRODUCTION

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INTRODUCTION

AUTHORIZATION

The project was authorized by the State of New Jersey Division of Purchase and Property through the New Jersey Department of Environmental Protection (NJ DEP), Hazardous Site Mitigation Administration. This work assignment constitutes Task 1 of that agreement.

BACKGROUND

The C.P.S./Madison site, located in Old Bridge Township in Middlesex County, New Jersey, consists of two active industrial plants (constructed in 1967) and the adjacent property. C.P.S. Chemical Company is engaged in the processing, conversion, and storage of organic chemical compounds, and Madison Industries, Inc. (formerly Food Additives, Inc.) is engaged in the production of zinc chloride and other chemical compounds.

The plants are located adjacent to the Runyan Pumping Plant and well field which supply potable water to the City of Perth Amboy. Pricketts Brook flows through both plant properties and discharges into Pricketts Pond which was constructed to increase recharge to the well field, in particular, the Bennett Suction Line wells.

The uppermost groundwater aquifer at the site is the Old Bridge Sand Aquifer which extends to an average depth of about 80 feet. Concentrations of metals and organic chemicals have been detected within the Old Bridge Sand Aquifer that are in excess of Federal and State drinking water standards. The highest concentrations of these contaminants have been found in a relatively narrow band running between the CPS plant site and Pricketts Pond. Because of this contamination, the Bennett Suction Line wells were abandoned in 1973.

Extensive studies and investigations have been conducted by others at the site since the early 1970s to define the extent of the problem. To date, no groundwater or sediment cleanup efforts have been initiated. In 1980, the New Jersey Superior Court ruled that a remedial action consisting of a slurry cutoff wall, groundwater recovery wells, and realignment of Pricketts Brook be implemented at the site. Preliminary plans and specifications were prepared by NJ DEP in 1982.

At the present time, there is still ongoing work being done by others at the site in addition to this work assignment.

The other projects include evaluation of groundwater treatment and discharge requirements and sediment removal from Pricketts Brook.

PURPOSE OF WORK ASSIGNMENT

The primary purpose of the Task 1 work assignment is to review the available information on existing site conditions. This review includes a detailed assessment of the results of previous site investigations, feasibility study, treatability study, and preliminary plans and specifications. In addition, existing information available in files at NJ DEP and the New Jersey Attorney General's offices were reviewed.

The purpose of this Task is to become familiar with the site conditions, to identify any significant data gaps, to identify the rationale behind the various remedial action components, to review and evaluate the design parameters or design criteria, and to establish a record of decisions made regarding the total remedial action concept. This report will therefore serve as the basis for the final design of the remedial action components.

This work assignment did not include generating any new data through testing, monitoring, sample collection or site surveys. Only existing available data were used in developing this design review report. Limitations of the existing information and recommendations for obtaining additional data as part of Task 2 are presented in this report. The results of any additional data obtained during Task 2 may therefore affect the conclusions and recommendations presented in this report.

The scope of work performed in the Task 1 work assignment includes the following:

1. Develop a set of objectives and/or design assumptions for the remedial action design.

2. Develop a preliminary assessment of the viability, feasibility, or constructability of the existing plan and identify major problems or concerns with the plan.

3. Recommend modifications to the plan in order to satisfy the identified objectives or to mitigate the identified concerns.

4. Identify significant data gaps which must be filled in order to complete the design of the remedial action or which may provide beneficial input into the design to assure suitable performance of the remedial action.

5. Prepare an order-of-magnitude estimate of the probable construction cost and schedule for implementing the remedial action.

6. Establish appropriate levels of health and safety protection for work performed during supplemental field investigations and during construction.

<u>DOCUMENT MANAGEMENT</u>

All of the documents obtained for NJ DEP that pertain specifically to the C.P.S./Madison site, including reports, memos, letters, laboratory or survey data, plans, drawings, specifications, etc., were controlled. Each document was assigned a control number and recorded on the C.P.S./MADISON Project Document Summary. The Summary listed all copies of the documents and their chronology. A copy of the Document Summary is attached in Appendix A.

A list of other general references used in developing the predesign report is presented in Appendix B.

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Section 3
PRICKETTS BROOK REALIGNMENT

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PRICKETTS BROOK REALIGNMENT

INTRODUCTION

This section presents the engineering evaluation of the proposed realignment of Pricketts Brook. The primary purpose for realigning the brook is to divert stormwater around the plant areas and thereby avoid further surface water discharges of contaminants.

The preliminary remedial action plan consists of relocating the brook for a distance of about 3,200 feet, beginning in a boggy area east of the Rebel One Corporation plant site and ending at the northern end of Pricketts Pond. The new channel is shown to be about 35 feet wide, between 2 and 18 feet deep, with (5:1) (horizontal:vertical) side slopes.

The following are specific objectives to be satisfied in the final design of the brook relocation:

1. Provide a channel capacity sufficient to handle a 100-year storm event without flooding of the C.P.S./Madison plant sites.
2. Maintain velocities within the channel high enough to limit sediment deposition.
3. Avoid construction on Rebel One Corporation property.
4. Avoid future contamination of the new channel due to surface runoff from the C.P.S./Madison plant sites.
5. Avoid interference of the new channel with highly-contaminated areas of groundwater.
6. Limit excavation depths and quantities.
7. Minimize potential side slope erosion.
8. Minimize gulleying due to surface wash into the channel from overland flow off of adjacent property.
9. Minimize the quantity of recharge to the proposed decontamination wells.
10. Minimize the loss of usable yard area at the Madison Industries plant site or the C.P.S. expansion area.
11. Maximize use of the existing channel wherever possible.

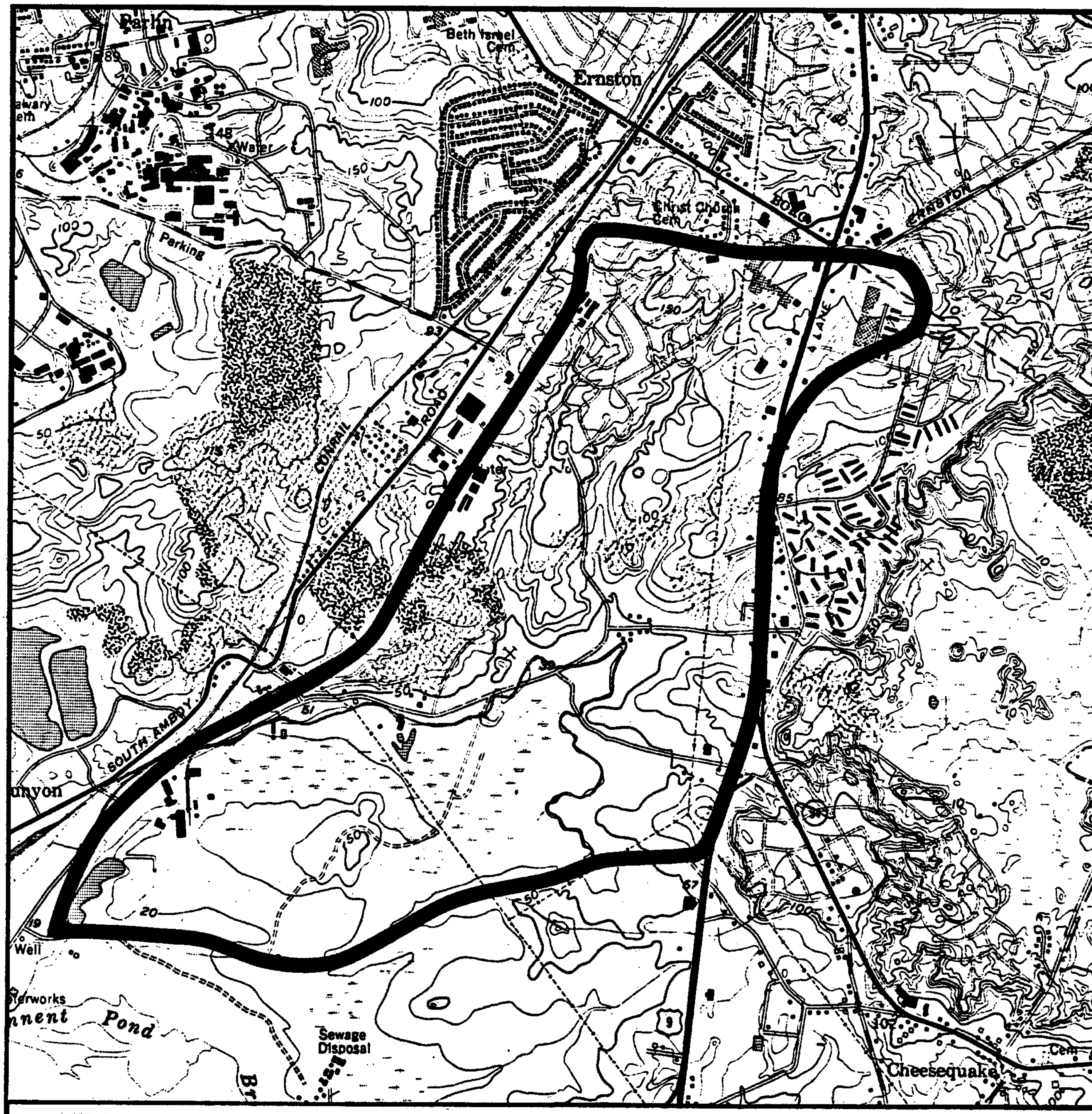
WATERSHED CHARACTERISTICS

The Pricketts Brook watershed upstream of the outlet of Pricketts Pond is outlined in Figure 3.1. The watershed divide is pourly defined in the urbanized areas in the northern portion of the watershed, but inaccuracies in plotting the watershed boundary are expected to be insignificant. The watershed area is approximately 1.8 square miles. Approximately 25 percent of the watershed is urbanized, with about 90 percent of the urbanized area in the northern portion of the watershed. The length of the watershed is approximately 14,000 feet. Elevations range from about 150 feet to 20 feet mean sea level. The distribution and characteristics of the soils within the Pricketts Brook watershed are presented in Appendix C.

FLOOD POTENTIAL AND WATER SURFACE ELEVATIONS

The N.J. Bureau of Floodplain Management (BFM) has evaluated four alternatives for the proposed relocation of Pricketts Brook. These alternatives were developed from the original Pricketts Brook channel realignment shown in the preliminary design plans. The discharge from the 100-year recurrence flood was calculated for each alternative based on empirical equations developed by Stankowski (1974). The equations for various flood frequencies and the parameters used in the equation are summarized in Table 3.1, which is reproduced from the original report. The equations predict discharge based on basin characteristics and an estimate of the amount of impervious area in the watershed. The amount of impervious area is calculated as a function of population density. These equations were developed through regression analysis of flood data from 103 gaged sites in New Jersey. The depth of flow in the channel and flow velocity for the 100-year recurrence flood were determined using BFM's in-house computer program.

Two of the alternatives were developed by NJ DEP, one by Wehran Engineering and one by Converse Consultants. Both NJ DEP alternatives involved truncating the upstream end of the new channel relative to the realignment shown in the preliminary design plan. One of the NJ DEP alternatives also included on extension of the downstream end of the channel. The Wehran proposal also involved truncating the upstream end. The Wehran proposal also consisted of extending the downstream end and truncating the upstream end, but raises and increases the slope of the channel slightly. The Converse alternative included a meander loop which would increase the length of the channel by about 1,000 feet. The BFM considered all plans acceptable from a hydraulic standpoint. Flow depths for the design flood were calculated at 2.26 feet for the two NJ DEP plans and 2.16 and 2.37 feet for the Wehran and Converse plans,



LEGEND

Watershed Boundary

-N-

SCALE
1 : 24,000

0 2000 Feet

Figure 3.1
Pricketts Pond Watershed Area

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Table 3.1 Equations for Calculating Peak Discharge, From Stankowski, 1974

Regional equations	Standard error		
	+%	-%	Average %
$Q_2 = 25.6\ A^{0.89}\ S^{0.25}\ St^{-0.56}\ I^{0.25}$	59	37	48
$Q_5 = 39.7\ A^{0.88}\ S^{0.26}\ St^{-0.54}\ I^{0.22}$	59	37	48
$Q_{10} = 54.0\ A^{0.88}\ S^{0.27}\ St^{-0.53}\ I^{0.20}$	60	38	49
$Q_{25} = 78.2\ A^{0.86}\ S^{0.27}\ St^{-0.52}\ I^{0.18}$	62	38	50
$Q_{50} = 104\ A^{0.85}\ S^{0.26}\ St^{-0.51}\ I^{0.16}$	64	39	52
$Q_{100} = 136\ A^{0.84}\ S^{0.26}\ St^{-0.51}\ I^{0.14}$	68	40	54

where

Q_T = peak discharge for T-year recurrence interval, in cubic feet per second.

A = drainage area in square miles.

S = main-channel slope, in feet per mile, defined as the average slope of the main channel between points 10 and 85 percent of the distance upstream from the runoff site to the watershed boundary.

St = surface storage index, in percent of drainage area occupied by lakes and swamps and increased by 1.00 percent.

I = index of manmade impervious cover, in percent, which can be determined for existing and future development conditions from population data and projections by use of the relation:

$$I = 0.117\ D^{0.792 - 0.039 \log D};\ 1\% \leq I \leq 100\%$$

where

D = basin population density in persons per square mile.

respectively. Flow velocities were calculated at 4.13 feet per second for the NJ DEP plans and 4.12 and 3.84 feet per second for the Wehran and Converse plans. Each plan incorporated a 1-foot deep, five-foot bottom width low flow channel at 2:1 (horizontal:vertical) sideslopes. The BFM recommended either of the NJ DEP plans over the Wehran and Converse plans because they would minimize disturbance of the wetland and would result in the least soil disturbance.

The basin characteristics and "urbanization factor" used in the Stankowski equation are in close agreement with the values calculated by CH2M HILL. The empirical equations are based on a substantial data base, and are presumed to be reliable within the maximum calculated standard error shown in Table 3.1.

DESIGN CRITERIA AND ASSUMPTIONS

In evaluating the proposed, Brook realignment, certain design criteria were established and assumptions made. These criteria and assumptions are based on information obtained from the existing available data previously generated for the site and on engineering judgment and experience with similar projects. The following is a list of the design criteria and assumptions made for this evaluation:

1. Native soil materials consist primarily of sandy gravels with no significant fine-grained material or boulders. These native materials are highly susceptible to erosion due to surface wash, as evidenced by severe gulleying along the existing channel.

2. The existing channel is prone to sediment build-up, but not to severe channel scour, even at abrupt changes in channel direction. To minimize sediment build-up, channel velocities should be maintained at a minimum of two feet per second for flows from a 10-year recurrence interval rainfall event.

3. The new channel will be excavated less than three feet below the prevailing groundwater table elevation. Flow in the existing stream is intermittent, and the new channel bottom is also expected to occasionally be dry.

4. Groundwater within the area of the new channel outside of the proposed containment wall may be slightly contaminated.

5. The existing ground surface varies from a high of about +37 feet mean sea level (msl) in the northeast portion

to a low of about +17 feet msl in the southeast portion.

6. The new channel must be designed for containment of a flood resulting from a 100-year storm event. However, flooding of the open field northeast of the C.P.S. plant site is a natural and continuing condition and does not need to be prevented following the brook realignment.

7. Underground utilities within the area of the proposed realignment include the MTSA sewer and an abandoned section of the Bennett Suction line between wells 10 and 13.

8. There is no restriction to use of the property east of the C.P.S./Madison plant sites for the new channel.

9. The area is susceptible to freezing weather with a maximum (extreme value) frost depth of 36 inches.

10. A minimum separation of 100 feet should be maintained between the proposed slurry wall and the new channel.

11. Stormwater runoff upslope of the C.P.S./Madison plant sites should be diverted away from the plant areas.

DISCUSSION

Alignment

The proposed channel alignment shown on the preliminary plans is expected to adequately handle runoff from the upstream drainage basin in accordance with the design objectives. However, difficulties in construction are anticipated with this alignment.

At the upstream end of the proposed channel, the new channel extends into a boggy area located on Rebel One Corporation property. Improved drainage conditions may adversely affect natural water levels in the bog. Construction of the new channel will also cause considerable disturbance to vegetation within both a wooded area and the bog.

The surface grades in the northeastern portion of the proposed channel are relatively high, exceeding 36 feet above mean sea level. Construction of the new channel will result in an unnecessarily deep and wide excavation. The quantity of materials to be excavated can be substantially reduced if the new channel were constructed further to the northwest in this area.

It is not the intent of the new channel to improve or repair the conditions within the existing channel. If the new channel were to depart from the existing channel about half-way along the rear of the CPS site, the disturbance to the vegetation within the bog and wooded area on Rebel One Corporation property would be avoided, and excavation quantities minimized. The existing 90-degree bend and severe gulleying at the eastern corner of the CPS site would not be changed, however.

Channel modifications may be necessary downgradient of Pricketts Pond if studies show that this portion of the channel will not be able to contain flows from a 100-year recurrence interval storm.

At the downstream end of the proposed channel, excavation for the channel will involve construction within the most highly contaminated area of Pricketts Pond. Health and safety precautions during construction will therefore be of significant concern. In addition, future sediment removal or other remedial action will be hampered by the continued discharge into the pond.

The proposed channel also discharges into Pricketts Pond in the area where the proposed decontamination wells are to be located. The channel will therefore serve as a source of additional recharge or infiltration to the recovery wells and thereby increasing the quantities of groundwater to be pumped.

If the downstream end of the new channel were located downstream of Pricketts Pond, then construction within the heavily-contaminated areas would be avoided, sediment removal might be facilitated, and recharge to the recovery wells would be minimized.

<u>Channel Construction</u>

Severe gulleying of the stream banks is evident in the existing channel at the east corner of the C.P.S. property. This gulleying is primarily a result of surface wash down the exposed bank. Measures to divert or collect overland flow prior to washing into the channel should be provided in the new channel to minimize the potential for severe gulleying to occur. The proposed channel cross-section has very flat (5:1) side slopes which are relatively susceptible to this gulleying by exposing a large surface area to rainfall and runoff. Steeper side slopes may actually be less prone to gulleying. The stability of slopes as steep as (3:1) is considered adequate due to the dense sandy gravels present, and the observed steep slopes of the existing man-made channel at the rear of the C.P.S. site. In addition, erosion control measures such as gabions, riprap, or stable vegetation should be provided along the entire length of the new channel. This protection would minimize gulley formation and channel side slope erosion.

The proposed cross-section has a bottom width of 35 feet, which provides a very wide meander belt for normal stream flows less than the 100-year flood event. Equilibrium conditions with respect to bottom scour and/or sediment deposition could create a maintenance nuisance with such a wide stream bottom.

A low-flow channel designed to handle 10-year or lower frequency flood events would provide a more stable channel for erosion/sedimentation equilibrium as well as decrease excavation quantities. Erosion control measures such as gabions or riprap should be provided along the banks of this low-flow channel to restrict meander development.

Construction sequencing of the channel realignment with respect to other remedial action plan elements, including the slurry wall and groundwater recovery wells, is critical. If the channel is dredged too soon, contaminated groundwater may be redirected further to the southeast by providing a line of discharge for the aquifer similar to the existing stream. If the channel is constructed too late, flooding of the plant sites or continued discharge of contaminated runoff from the plant sites into Pricketts Pond may result. Construction sequencing is discussed further in Section 7, Construction Cost and Schedule.

CONCLUSIONS AND RECOMMENDATIONS

The new channel should avoid the existing boggy area at Rebel One Corporation and the high ground area at the northeast side of the C.P.S. site, and should therefore be rerouted starting at a point along the existing man-made channel on the C.P.S. site.

The alignment should pass near the rear fence line of the Madison Industries site and discharge downstream of Pricketts Pond to facilitate sediment removal and decontamination. The recommended realignment is shown in Figure 3.2.

The channel cross-section should consist of at least two segments, a small section for normal flows and a wider section for passing the 100-year flood. Erosion protection, such as riprap or gabions should be provided along the entire length of the new channel.

Stormwater collection, retention, and discharge should be provided for all runoff from the enclosed C.P.S./Madison plant areas. Treatment of runoff may also be needed.

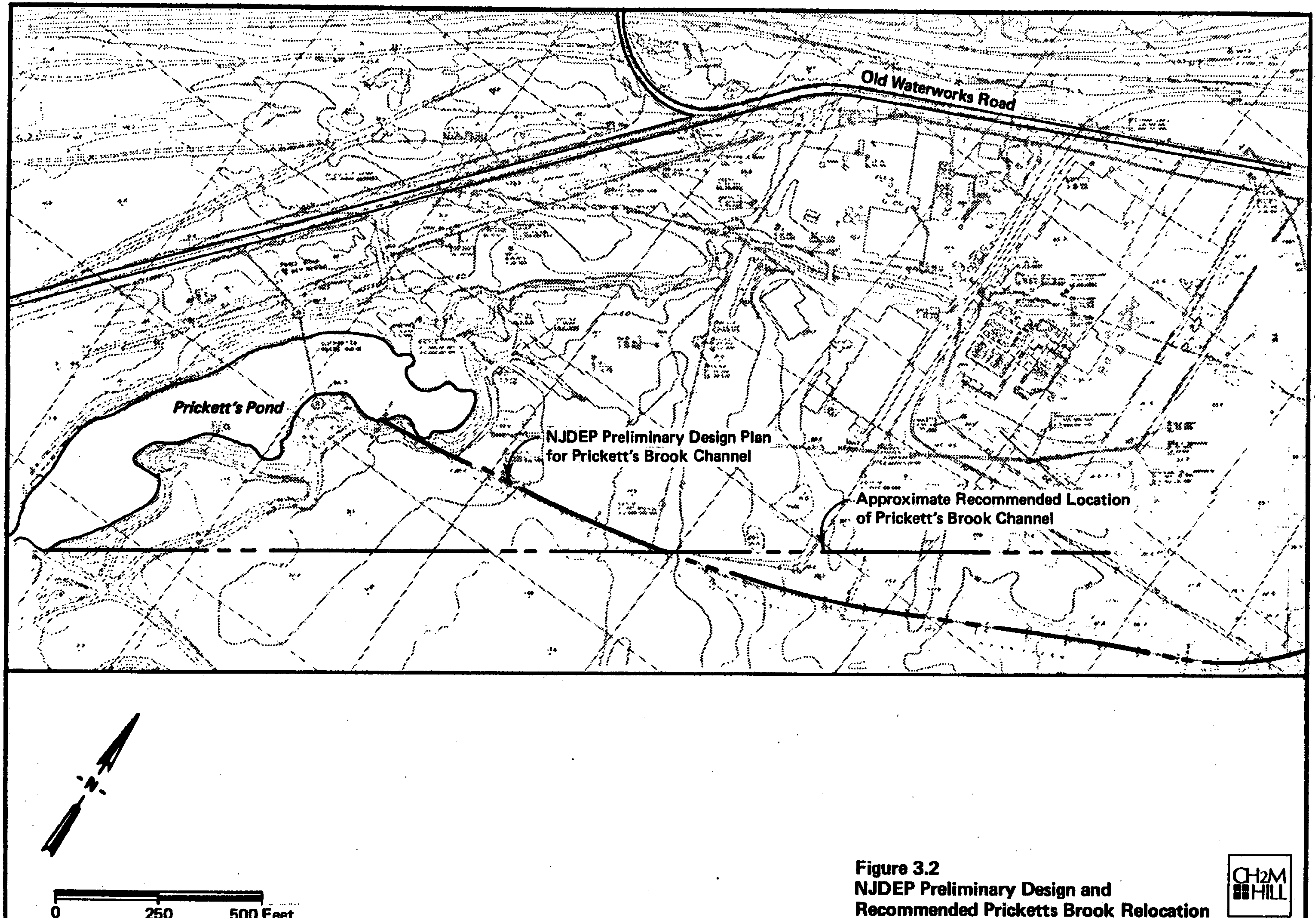

Figure 3.2
NJDEP Preliminary Design and
Recommended Pricketts Brook Relocation

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Upgradient stormwater west of Old Waterworks Road should be diverted around the plant site.

A topographic survey should be made along the modified alignment of the new Pricketts Brook channel to verify the approximate grades shown on the preliminary drawings and along the channel downstream of Pricketts Pond.

Once the final selection has been made for the Pricketts Brook relocation, the empirically derived peak discharge should be supported by a rainfall-runoff computer simulation model (Stanford Watershed Model) based on a design storm (e.g., 100-year recurrence, 24-hour duration) and detailed evaluation of the watershed. Using the cross sections for the relocated channel, a flood routing program (HEC-2) will be used to calculate water surface elevations and flow velocities.

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Section 4
SLURRY CONTAINMENT WALL

Section 4
SLURRY CONTAINMENT WALL

INTRODUCTION

This section presents the evaluation of the proposed slurry containment wall to be constructed around the CPS/Madison sites. The primary purpose of the slurry wall is to enclose the contaminated groundwater by providing a barrier to groundwater flow.

The preliminary remedial action plan consists of constructing a 360° encapsulation of the contaminated area. A soil-bentonite slurry trench cutoff wall is proposed to be constructed from the C.P.S. plant site to Pricketts Pond and from Old Waterworks Road to the rear of Madison Industries' plant buildings. The wall is proposed to be between 50 and 100 feet deep, keying into the South Amboy Fire Clay, for a total length of about 5,100 feet.

The following are specific objectives for the design of the slurry containment wall:

1. Provide a continuous, 360° containment of the groundwater within the contaminated section of the Old Bridge Sand Aquifer, enclosing the "Worst Case Areas" identified in the 1980 feasibility study.

2. Prevent unacceptable rates of seepage or potential cross-gradient dispersion of contaminants from the enclosed plant areas into the surrounding (decontaminated) groundwaters.

3. Minimize the quantities of groundwater to be recovered by the maintenance wells.

4. Minimize adverse effects due to fluctuations in groundwater levels, fluctuations in groundwater divides, or anticipated rise in groundwater levels upgradient of the wall.

5. Minimize construction interference with or damage to existing industrial plant buildings or operations and minimize clearing of the existing wooded area on the City of Perth Amboy property near Pricketts Pond.

6. Provide adequate long-term support for parking, plant access roads, railroad spur lines, and utility line crossings of the trench.

DESIGN CRITERIA AND ASSUMPTIONS

In evaluating the proposed slurry containment wall, certain design criteria were established and assumptions made based on existing available information and on engineering judgment and related experience. The following is a list of the design criteria and assumptions made for this evaluation.

1. Native soil materials within the Old Bridge Sand Aquifer consist of very permeable sandy gravels to the top of the South Amboy Fire Clay. The South Amboy Fire Clay is continuous and non-leaking, and present at an elevation of between -25 and -79 feet msl.

2. Groundwater table elevations are at generally about the existing ground surface at the north end of the site and at the level of Pricketts Pond at the south end.

   Subsurface groundwater flow generally follows the shape of the surface drainage patterns. A groundwater divide may be present in the southern portion of the Madison Industries plant site.

3. Groundwater levels within the enclosed area will be controlled by positive pumping from maintenance wells. The maximum differential piezometric head between the groundwater on either side of the wall will be less than 25 feet. The rate of groundwater maintenance from within the enclosed area could be significantly affected by the continuity of the South Amboy Fire Clay, the complete enclosure of the wall, and quantity of rainfall.

4. Along most of the proposed wall alignment, groundwater in contact with the wall will not be highly contaminated. In the area between Madison Industries and Pricketts Pond, this groundwater is highly contaminated including high concentrations of organic constituents and very low pH.

5. The industries will remain in operation during and after the remedial activities and will continue as a source of contamination of the groundwater. Also the highly contaminated soils under the industries physical facilities will remain a source of contamination of the groundwater.

6. The top of the wall should be nearly flat, with a maximum longitudinal slope of about 0.5 percent. The top of the wall is to be maintained above the anticipated high groundwater level outside of the wall; the ground surface above the wall is to be maintained

above the 100-year flood level to prevent flooding of the plant sites.

7. Underground utilities known to exist in the area of the proposed wall include the MTSA sewer, the Bennett Suction Line and wells and water service to each plant alongside Old Waterworks Road.

8. The area is susceptible to freezing weather with a maximum expected frost depth of 36 inches.

DISCUSSION

The performance of the slurry wall and associated groundwater maintenance wells is strongly dependent on the integrity and continuity of the South Amboy Fire Clay. If the clay were absent, discontinuous, or fractured, then the potential for contaminant migration beneath the wall would be higher and the quantities of groundwater recovered by the maintenance wells could be increased.

Soil borings were made along the proposed wall alignment by NJ DEP at approximately 250-foot intervals. The South Amboy Fire Clay was encountered in most of the borings. However, in the northeastern portion of the C.P.S. site, the soil borings were inadvertently completed in a shallower clay deposit and did not extend to the top of the South Amboy Fire Clay. Because the integrity of the clay is essential to the performance of the containment system and because its integrity is questionable in the northeastern portion of the site, additional subsurface information to verify the presence of the South Amboy Fire Clay in this area is considered critical.

Methods and Materials of Construction

Along Old Waterworks Road, the constructibility and suitability of the proposed wall is also questionable. The wall in that area will be more than 80 feet deep; the space required for conventional slurry trenching and backfilling is severely limited.

Traditionally, a clear construction area approximately 70 to 80 feet wide is generally required for spreading out the excavated trench material and mixing the soil-bentonite backfill. Because of the limited space available alongside Old Waterworks Road, the road would have to be closed, traffic detoured or rerouted during construction, and the roadway surface reconstructed. If the trench is located too close to the existing buildings or zinc stockpile, the foundation support for these facilities could be endangered.

Suitable equipment for constructing a slurry trench to depths greater than 50 feet, such as drag lines or clam-shell buckets, are relatively slow in productivity. In addition, because the soil-bentonite backfill can be laid at a slope of only about (7:1), the length of the open slurry trench at the ground surface will be about 700 feet for a wall as deep as 100 feet. Because of the slow construction procedures and long length of open trench, access to the plant sites including both roadway and railroad access will be interrupted for a considerable duration. Alternate temporary access to the plant sites would likely be needed.

Using drag lines or clam-shell buckets, the slurry trench will probably be more than 3 feet wide, and at the ground surface may actually be more than 10 feet wide. Because of this broad width of the top of the trench, a traditional soil-bentonite backfill would most likely not provide sufficient subgrade support to the access roadways and railroad spur lines. High groundwater conditions in this area will require that the top of the wall be located very near the ground surface, further aggravating the poor subgrade conditions.

To alleviate some of the potential difficulties, alternative wall materials or methods of construction were briefly reviewed.

<u>Eliminate the Upgradient Portion of the Wall</u>. If the portion of the slurry containment wall along Old Waterworks Road were not constructed, then problems with site access, foundation support, or high groundwater levels would not be experienced. However, the amount of groundwater to be collected by the maintenance wells would increase by approximately 250,000 gallons per day. Because this option does not meet the intent of the court-ordered remedial action or satisfy the design objectives, the alternative was not considered further.

<u>Concrete Backfill</u>. Conventional ready-mix concrete could be used for backfill of the slurry trench. The concrete would be placed by tremie methods in discrete sections. Temporary steel casing pipe coated with a bond-breaker would be used as formwork to construct alternating sections of the wall.

The use of a concrete backfill has several advantages. Since the wall is poured in short, vertical sections, the length of the open trench may be considerably reduced, which would limit disruption of site access and limit potential loss of foundation support for the buildings. Vertical sections also permit the elevation of the top of the trench to be changed rapidly in order to accommodate a relatively steep rise in the groundwater table or surface grades. The concrete is poured directly into the slurry trench so that mixing of backfill materials on Old Waterworks Road is avoided. The concrete offers outstanding subgrade support for the railroad, roadways, parking areas, buildings, zinc stockpile, and utility service connections. Because the upgradient groundwater is relatively free of contaminants, there is no expected deterioration of the concrete backfill.

The primary disadvantages of concrete backfill are its relatively high cost, nearly five times more than soil-bentonite, and potentially lower rate of construction due to setting of casing pipe and pouring of sections.

Steel Sheet Piling. Conventional steel sheet piling could be driven to the top of the South Amboy Fire Clay in lieu of a slurry trench. The advantages of this method include negligible loss of subgrade support as would occur with trenching, capability to rapidly change grade at the top of the wall, and ease of utility crossings. Upgradient groundwater quality will not rapidly deteriorate the piling, although corrosion at the fluctuating water table could eventually lead to deterioration.

The feasibility of installing steel sheeting by driving or vibrating for a length of more than 80 feet is highly questionable. Damage to the sheeting could easily result under these conditions and separation of the sheet pile interlocks could not be checked. In addition, steel sheet piles are substantially more permeable than soil-bentonite and cost nearly twice as much. This option is therefore not considered appropriate.

Injection (grout) curtain. A relatively impermeable barrier could be constructed in relatively porous, granular materials by injecting chemical grout into the soil matrix. The grout would be injected under pressure into a series of boreholes located 3 to 5 feet apart in approximately three overlapping rows. The advantages of this method are similar to those of steel sheet piles; no trench is excavated so that foundation subgrade support, site access, continued flow of traffic, and rapid changes in grade can all be easily accommodated.

It is difficult to predict the amount of penetration of the chemical grout or the effective radius of penetration from the borehole. Also, penetration will vary depending on soil material type; in relatively silty or clayey zones, penetration may be negligible. It is also difficult to maintain vertical plumbness of the borehole throughout the more than 80 foot depth of the curtain, so that gaps in the wall are possible and difficult to check. Finally, although the groundwater quality is not expected to adversely affect the chemical grout, the longevity or service life of chemical grouts is uncertain. Therefore, the integrity of the wall is difficult to ensure.

Special Foundations. To improve foundation subgrade support beneath roadways and railroad lines, special foundations could be constructed to "bridge" over a traditional soil-bentonite wall. Such foundations would not alleviate many of the problems associated with construction of the slurry trench and backfill. Construction of such structures is likely to be cumbersome, but not impractical.

Alignment

The proposed alignment of the wall in the rear of the Madison Industries plant is located relatively close to an existing building and will cause substantial disruption of the plant storage yard during construction. Because of surface grading changes needed to accommodate the wall, and because of potentially poor subgrade support, the permanent usable yard storage area at Madison Industries will be substantially reduced if the wall cuts through the center of that area. Instead, the wall could be located near the rear of the storage yard, parallel to the proposed Pricketts Brook channel.

Construction of both the slurry trench wall and the brook realignment will require the clearing of relatively wide strips through the existing wooded area on the City of Perth Amboy property. It is considered preferable to keep the amount of clearing to a minimum. Along the southeast portion of the wall, this could readily be accomplished by running the wall and brook parallel to one another with minimum separation between them.

Similarly, along the existing dirt road (Old Waterworks Road) on the western portion of the wall, clearing could be held to a minimum by running the wall parallel to the dirt road. Spreading and mixing of soil-bentonite backfill could be performed on the surface of the dirt road. If the wall were located alongside the dirt road, then there would be less interference of the slurry trench construction with the Bennett Suction Line piping, although overhead electrical utility lines may need to be relocated, and the construction may encounter an existing water main.

The "Worst Case Areas" delineated in the 1980 feasibility study are shown to end abruptly at Pricketts Pond. However, based on the results of recent sediment and water sampling and analysis (by NJ DEP), high contamination is present throughout the northernmost section of the pond. To enclose the "Worst Case Areas" in accordance with the design objectives, the wall should be constructed approximately 400 feet further to the southwest, through the middle of

Pricketts Pond. This would involve constructing a dike through the pond approximately 10 to 15 feet high. Materials for constructing the dike can be readily obtained from the excavation for the new Pricketts Brook channel. Sediments on the bottom of Pricketts Pond could be left in place inside the enclosed area and removed by dredging the pond bottom outside of the toe of the dike. Sediments immediately beneath the dike would not be easily removed, although metal-contaminated sediments could be dredged prior to fill placement, if desired.

Consideration was given to an option of installing the downgradient section of the wall immediately westward of the existing fence at Madison Industries. This would significantly reduce the area to be enclosed by the wall and the quantity of groundwater to be recovered by the maintenance wells. The groundwater southwest of this wall location could be decontaminated by pumping from recovery wells. However, because of the high levels of organic contamination and low pH of the groundwater in that area, the risk of irreversible deterioration of the soil-bentonite backfill is considered significant. If the wall did deteriorate, then contaminants would migrate into the surrounding (decontaminated) groundwater. Also, decontamination of this highly contaminated area would be more difficult. The area (and volume) of the unenclosed contamination zone would approximately double and the contaminant levels in the additional area would be much greater. In particular, metals removal from the zone immediately downgradient of the fence would require that decontamination wells operate at higher flow rates and/or for a much longer period.

The proposed wall alignment has discrete points where the alignment changes direction, making either very sharp or very slight angles. Where these angles are excessively acute or obtuse, the construction equipment will not readily be able to excavate and backfill adjacent sections of the wall. Smooth, large-radius curves would eliminate very slight angles and increase acute angles to approximately 90 degrees. The recommended locations for the proposed slurry containment wall and Pricketts Brook channel are shown in Figure 4.1. The original NJ DEP proposed locations are also shown.

Stormwater Drainage

Most of the stormwater which will fall on the site within the enclosed area will percolate directly to the groundwater table. However, a significant quantity will flow along existing drainageways as surface water runoff. By collecting and pumping this stormwater runoff, fluctuations in the operation of the maintenance wells could be held to a

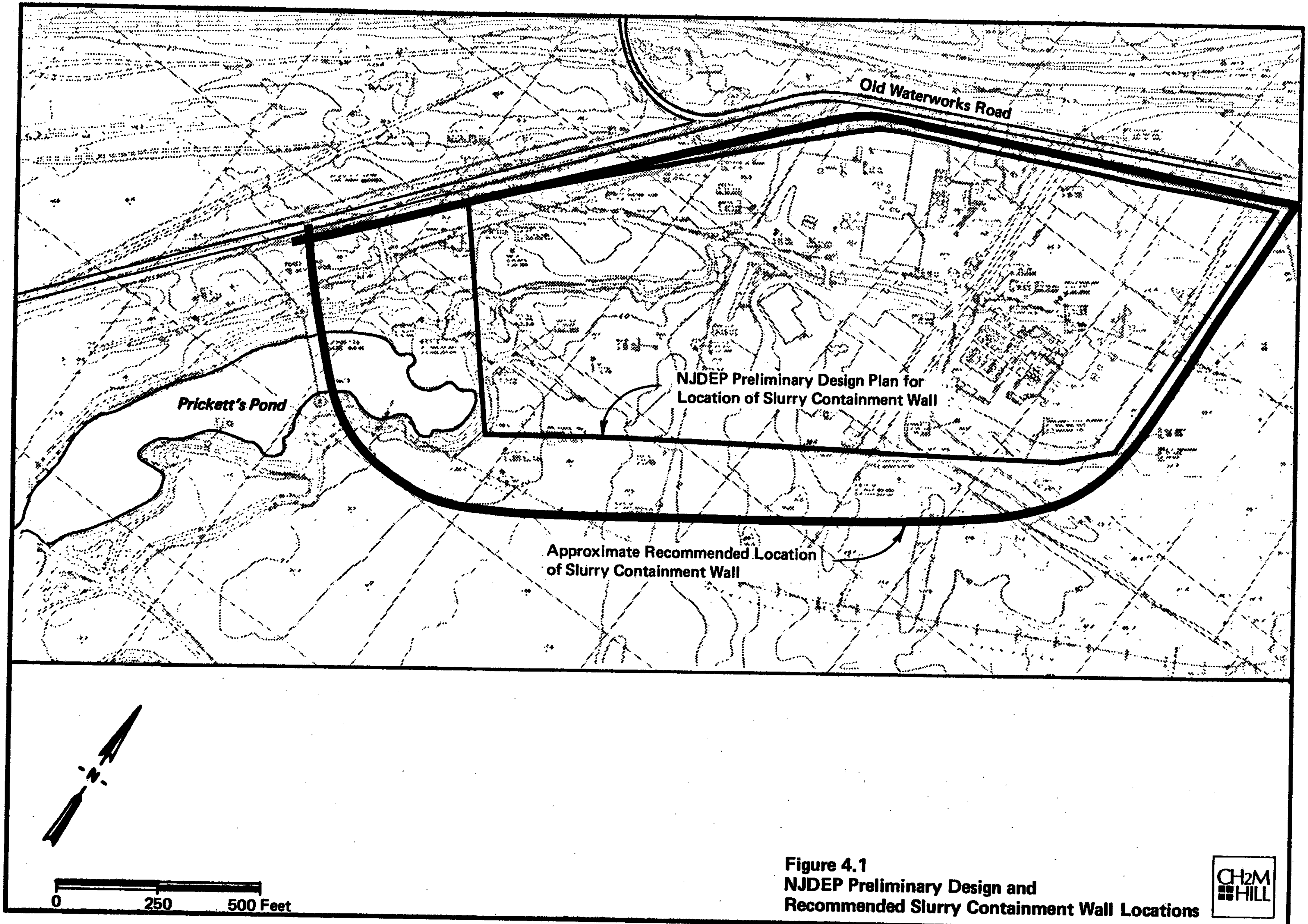

Figure 4.1
NJDEP Preliminary Design and Recommended Slurry Containment Wall Locations

minimum. Stormwater runoff may require less treatment prior to discharge than if the water is permitted to percolate to the groundwater and be removed by the maintenance wells.

The preliminary design plans indicate a culvert through the slurry wall where the existing Pricketts Brook enters Pricketts Pond. Because the water within the existing brook channel may be significantly contaminated, stormwater runoff through a culvert should be avoided. Instead, the stormwater collection, retention, and discharge system described above should be designed to handle stormwater falling within the enclosed area.

Onsite stormwater should be controlled by providing shallow ditches along the inside face of the slurry contaminant wall wherever surface grades warrant. Stormwater outside of the wall should be diverted around the enclosed area. Two principal ditches, one extending from the railroad spur lines at Old Waterworks Roads southward to discharge with the new Pricketts Brook channel, and the other extending from the railroad lines southwestward to discharge into Pricketts Pond could be used to divert upgradient surface water away from the enclosed area.

Groundwater levels upgradient of the proposed slurry containment wall are expected to rise as a result of the wall installation. To avoid saturating the area along Old Waterworks Road the drainage ditches should be designed to intercept groundwater flow and to divert the groundwater around the wall.

CONCLUSIONS AND RECOMMENDATIONS

Special backfill materials should be provided along Old Waterworks Road where the proposed slurry containment wall crosses the plant access roads and the railroad spur lines. Concrete backfill placed in sections or "panels" approximately 50 feet long is recommended. The concrete backfill sections should extent at least 25 feet beyond the edge of the road or railroad limits.

The wall alignment should be extended further to the southwest through the center of Pricketts Pond to enclose the areas of greatest contamination. The south portion of the wall should be located parallel to the proposed Pricketts Brook channel and the northwest portion should be located parallel to the existing dirt road. Along Old Waterworks Road, the wall should be located at least 40 feet away from the C.P.S./Madison plant buildings. Excessively obtuse or acute angles should be eliminated by providing large-radius curves where the wall alignment changes directions.

Onsite stormwater should be controlled by providing a stormwater collection, retention, discharge system to minimize percolation to the maintenance wells. Offsite stormwater should be diverted around the slurry containment wall; along Old Waterworks the drainage ditches should be designed to intercept groundwater flow as well.

The presence and thickness of the South Amboy Fire Clay in the northern portion of the wall should be verified. At least two borings should be made; one to a depth of at least five feet below the top of the clay, and the other to a depth of at least two feet below the bottom of the Sayreville Sand, beneath the South Amboy Fire Clay.

Likewise, the presence of the South Amboy Fire Clay in the southwest portion of the wall near Pricketts Pond should be verified. Two borings should be made to a depth of at least five feet below the top of the clay.

At least one set of compatibility tests should be run on the proposed soil-bentonite backfill material using leachate collected from wells near Pricketts Pond. These tests should include a mineralogical examination of the effect of the leachate on the bentonite-soil matrix and a long-term laboratory permeability test on the proposed slurry backfill.

The following design criteria should be used in the design of the slurry containment wall:

Minimum width: 30 inches

Maximum permeability: 0.005 ft/day (1.76 x 10^{-6} cm/sec)

Minimum radius of turns: 400 feet

Maximum slope at top of wall: 0.5%

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Section 5
GROUNDWATER RECOVERY WELLS

Section 5
GROUNDWATER RECOVERY WELLS

INTRODUCTION

This section presents the evaluation of the proposed groundwater recovery wells. The purpose of these wells is to:

1. Maintain groundwater levels inside the area enclosed by the slurry containment wells, and

2. decontaminate the area outside of the wall to acceptable levels.

The preliminary plan for groundwater recovery wells consists of three maintenance wells inside the containment wall and three decontamination wells outside of the containment wall near the upstream portion of Pricketts Pond. An initial assessment of well logs, pump test data, and water quality data has been conducted.

The groundwater recovery wells will be designed to achieve the following objectives:

1. Minimize the continued migration of contaminated groundwater within the Old Bridge Sand Aquifer. In addition, preserve potable water quality within the aquifer downgradient of the site where municipal water supply wells are in use.

2. Reduce existing levels of contamination in the aquifer outside of the slurry containment wall to levels which meet the performance standards established by the NJ DEP. This level of cleanup is to be achieved within a reasonable period of time.

3. Discharge the contaminated groundwater in an environmentally acceptable manner using appropriate treatment, storage, and disposal techniques. Maintain discharge levels within the capacity of the current wastewater collection or treatment system.

4. Locate, install, and operate groundwater recovery wells in order to meet all environmental objectives in a cost-effective manner. This includes minimizing the quantity of recharge to the groundwater recovery wells, minimizing the quantity of water recovered during long-term maintenance, and optimizing the number, size, capacity and positioning of wells.

5. Maintain piezometric levels within the area enclosed by the slurry containment wall to prevent overtopping of the containment wall and flooding of surface facilities. In addition, minimize potential vertical migration through the South Amboy Fire Clay into the underlying Sayreville Sand.

DESIGN CRITERIA AND ASSUMPTIONS

The available information is not considered adequate for final design of the groundwater recovery well system. The preliminary design was developed according to the following criteria and assumptions:

1. The industries will remain in operation and continue as a source of groundwater contamination.

2. There is an unquantified but significant amount of contaminants in the unsaturated zone beneath the industrial facilities. Continued movement of these contaminants into the saturated part of the aquifer will occur regardless of future industrial operations.

3. The capacity of the existing wastewater collection and treatment system may limit the rate of groundwater recovery that is acceptable.

4. Decontamination wells may be located anywhere within the contaminant plume, without any property boundary or permitting constraints.

5. Maintenance wells within the area enclosed by the slurry containment wall should be located to minimize interference of the existing industrial operations.

6. Contaminants are present at all depths within the Old Bridge Sand Aquifer.

7. The cost of long-term groundwater recovery and treatment is a secondary design consideration; the reliability of the system in maintaining piezometric levels and minimizing contaminant migration are prime considerations.

8. Piezometric levels within and hydraulic characteristics of the Sayreville Sand and South Amboy Fire Clay are unknown.

9. The retention and migration behavior of contaminants in the aquifer are unknown. For example, concentrated zones of high specific gravity organic compounds may move along the interface with the lower clay layer,

which dips in a direction opposed to the principal water table gradient.

DISCUSSION

A groundwater recovery system can be designed, constructed, and operated that will meet the proposed environmental objectives. Current available information is insufficient, however, for complete design.

Maintenance Well Design Considerations

The principal design objective for the wells inside the proposed slurry wall is to prevent the water table from rising to the ground surface and overtopping the slurry wall. The suggested design parameters for determining pumpage requirements are:

- Pump at a sufficient rate to offset combined rainfall infiltration and groundwater seepage through the slurry wall.
- Maintain sufficient available storage in the unsaturated zone to handle infiltration from a 100-year recurrence, 24-hour duration rainfall event.

The proposed slurry wall design uses about 5,100 linear feet of wall enclosing an area of about 1,500,000 square feet. Average annual precipitation in the area is about 44 inches per year. The pumpage requirement needed to offset average annual precipitation was calculated assuming that all rainfall infiltrates and no evapotranspiration occurs.

The total average annual precipitation within the wall was calculated to be equivalent to about 80 gallons per minute (gpm).

Estimates of the amount of seepage through the slurry wall are based on an assumed seepage thickness of 70 feet, a slurry wall hydraulic conductivity at 0.005 ft/day (1.76×10^{-6} cm/sec), and a slurry wall length of 5,100 feet.

The volume of seepage through the wall, Q, is calculated as:

$$Q = KiA$$

where: K = Hydraulic conductivity, 0.005 ft/day
i = Hydraulic gradient through the wall. This gradient will be dependent on the pumping rate. The most economical pumping rate will be the one that provides no more than the required available storage for the design

rainfall event. A unit gradient through the wall was assumed, as discussed below.

A = Area of seepage, about 360,000 square feet.

Based on these assumptions, seepage through the wall would be approximately 10 gpm. The pumpage rate to offset both average rain fall infiltration and seepage rates would be approximately 90 gpm.

The 100-year, 24-hour rainfall for the area is about 7.5 inches. The volume of precipitation that would fall within the wall is estimated to be 938,000 cubic feet. The volume of water that could be stored in the upper soil was determined by assuming a unit gradient across a five-foot thick slurry wall and a water table at the ground surface outside of the wall (wet season conditions). In addition, soil porosity was assumed to be 0.35 and antecedent moisture conditions were assumed to be 50 percent of saturation. The available storage within the upper five feet of the soil profile was calculated to be about 1,313,000 cubic feet, which is greater than the 100-year, 24-hour rainfall event. Therefore, the available storage is sufficient to handle the design rainfall and an average pumpage rate of 90 gpm for the maintenance well system is adequate to offset infiltration and seepage through the slurry wall. A minimum water table depth of 10 feet would provide a sufficient safety factor to protect against the water table rising to the surface.

Operation and Placement of Maintenance Wells

Infiltration volumes may vary daily and wall seepage volumes will most likely vary seasonally. Pumping for water table maintenance within the slurry wall will be most efficient if the pumps are operated by float controls that activate the pump cycle when the available storage drops to the design minimum (water table at a depth of 10 feet), and cut off the pump cycle when the water table drops to a selected depth (20 feet). The water table would therefore be maintained within a depth range between 10 and 20 feet below the ground surface.

The selection of a maintenance well discharge rate must balance the advantages of having the capability to drop the water table quickly and the disadvantages of constructing and operating treatment and/or conveyance systems to handle the contaminated water.

It is recommended that the maintenance wells operating on float controls should be capable of pumping at a rate of no less than 3 times the required average pumpage rates of 90 gpm, or 270 gpm. It is recommended that three 90 gpm wells be placed at the approximate locations shown in Figure 5.1.

The recommended modification of the location of the slurry containment wall shown in Figure 4.1 would increase the enclosed area by about 30 percent over the NJ DEP preliminary design plan. The discharge rate of the maintenance wells should be increased to 120 gpm per well if the modified plan is constructed. The recommended locations and operating water table depth ranges (10 to 20 feet below ground surface) would remain the same.

Decontamination Well Design Considerations

The NJ DEP remedial and containment preliminary plan includes both a slurry containment wall with interior groundwater level maintenance wells and exterior decontamination wells. Based on current information on the distribution of contaminants, it may be feasible to extend the slurry containment wall and eliminate the need for the decontamination wells. The following evaluation of the proposed decontamination well system assumes that the slurry containment wall is located as shown in the NJ DEP preliminary design plans.

Hydraulic parameters of the Old Bridge Sand Aquifer were evaluated from pump test data obtained previously by Wehran Engineering. Values of transmissivity (T) and storativity (S) were calculated in order to assess the feasibility of the proposed design for decontamination wells.

Groundwater flow patterns near the upstream end of Pricketts Pond will be complicated by the presence of the containment wall and by recharge from the pond. In addition, the mixture and distribution of contaminants at the site are complex. These factors make it advisable to design the decontamination well system using a three dimensional groundwater flow/contaminant transport simulation model. Even with a computer simulation it will be difficult to assess the duration of pumping that will be required before the aquifer is restored to the water quality performance standards set forth by NJ DEP.

The Preliminary Design Plans show three decontamination wells outside of the proposed slurry wall. This configuration was evaluated to determine whether it would provide sufficient drawdown in the contaminated zone at realistic discharge rates. Historical data from water supply wells operated by the City of Perth Amboy indicate that 16-inch diameter wells in the aquifer are capable of sustaining steady state discharges between 500 and 700 gpm. It is assumed that significantly greater discharge rates (e.g., 2,100 to 5,000 gpm as proposed in the Dames and Moore

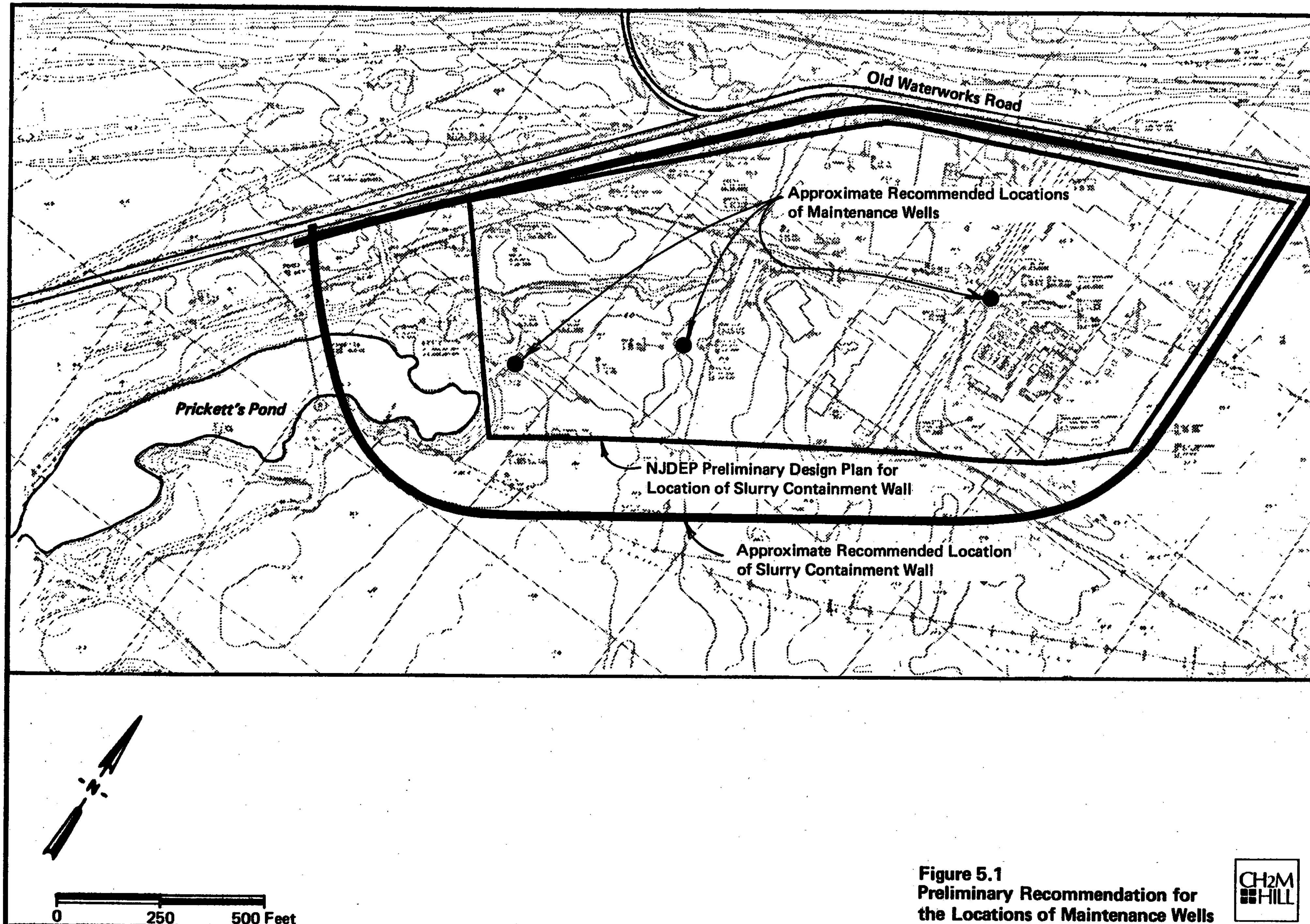

Figure 5.1
Preliminary Recommendation for the Locations of Maintenance Wells

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report) would pose significant problems for pretreatment and/or disposal of the contaminated water regardless of whether the aquifer could supply sufficient water to maintain such rates. No attempt was made to estimate the time required to clean the unenclosed contaminant zone.

The following approach was used in order to assess the feasibility of the preliminary design of the decontamination well system:

- o The downgradient extent of the contaminant plume was estimated.
- o The hydraulic characteristics of the contaminated aquifer were determined.
- o Decontamination well discharge rates and pump locations were determined that would provide a minimum water table drawdown (assume to be one foot) along the boundary of the contaminant plume within a selected time period after start up (assumed to be one week).

The decontamination well system developed through this approach was then compared to the system proposed by NJDEP.

The estimated boundary of the contaminant plume is shown in Figure 5.2. It is emphasized that the position of the boundary is highly speculative because of the absence of recent groundwater monitoring data and because of limitations in the distribution of the monitoring wells.

The results of a pump test conducted by Wehran Engineering were used to calculate the transmissivity (T) and storativity (S) of the Old Bridge Sand Aquifer. The results were interpreted using both semi-log plots of drawdown (s) versus time (t) and by matching log-log plots of s versus t with type curves of sT/Q versus Tt/r^2S. Table 5.1 is a summary of the pump test analysis.

Results from the semi-log plots yielded transmissivities between 5.92 and 10.79 ft^2/min (63,800 to 116,200 gpd/ft) and storativities between 0.011 and 0.027. The values of T presented in the Dames and Moore feasibility study ranged between 65,000 and 100,000 gpd/ft. The calculated storativity values were at the low end of the typical range for unconfined aquifers (0.01 to 0.30).

Log-log plots of the same data of drawdown versus time yielded transmissivities ranging from 4.01 to 7.43 ft^2/min (43,200 to 80,000 gpd/ft). Storativities ranged from 0.035 to 0.10. Average values of storativity and transmissivity from the data in Table 5.1 were calculated as 0.039 and

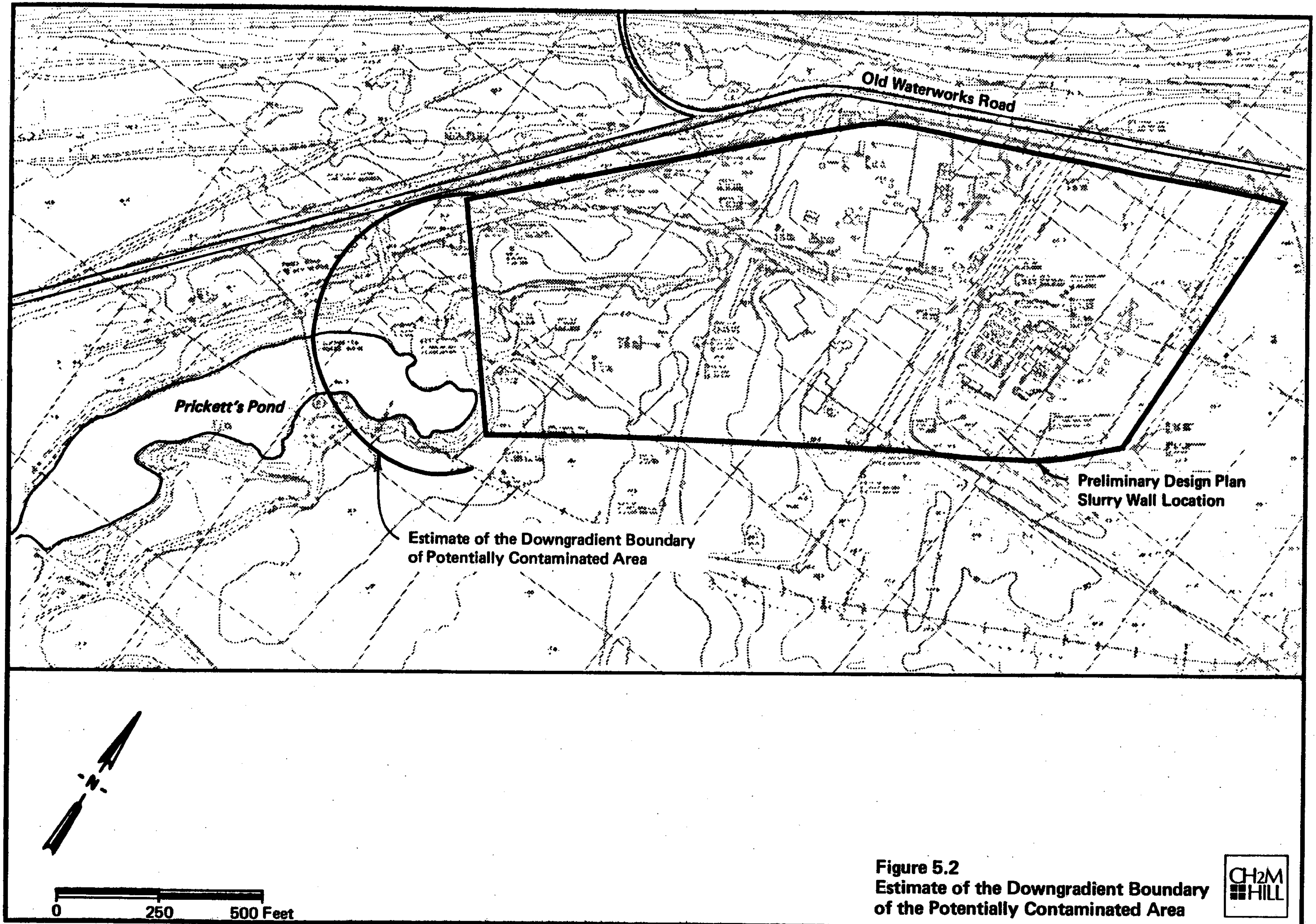

Figure 5.2
Estimate of the Downgradient Boundary of the Potentially Contaminated Area

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Table 5.1
HYDRAULIC CHARACTERISTICS FROM PUMP TEST DATA

LOG-LOG (TYPE CURVE) ANALYSIS

Pumping Well: T-1

Discharge Rate: 150 gpm
20.05 ft^3/min

Type Curve Sheet: Pump well penetrating the bottom three-tenths of the thickness of an unconfined aquifer--Figure 7 of Lohman, 1972, Groundwater Hydraulics, Geological Survey Professional Paper 708.

Type Curve: Observation wells with the top of the screen at one-half the thickness of the aquifer (Rc.=0.5b)--Figure 7D.

Observation Well	Distance from Pumped Well (ft)	Plotted Values		Hydraulic Parameters	
		s (ft)	t (min)	T (ft^2/min)	S
G&M	160	0.7	2.4	4.01	0.10
M-1	170	2.7	160	7.43	0.041
M-3	430	3.2	1050	6.27	0.035

SEMI-LOG PLOT ANALYSIS

Observation Well	Distance from Pumped Well (ft)	Plotted Values		Hydraulic Parameters	
		s (ft)	t (min)	T (ft^2/min)	S
G&M	160	0.42	25	8.74	0.019
M-1	170	0.62	58	5.92	0.027
M-3	430	0.34	80	10.79	0.011

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77,450 gpd/ft, respectively. The degree of variability in the plots suggest that there is considerable heterogeneity in the Old Bridge Sand Aquifer in the pump test area. An increase in the rate of drawdown near the end of the 24-hour duration pump tests was noted in each observation well, suggesting that the recharge area may be bounded in this area. It is recommended that future pump tests be conducted over a 48-hour period rather than the 24 hour period used in the Wehran tests.

A potential configuration for three decontamination wells pumping at 160 gpm each is shown in Figure 5.3. Placement of a single decontamination well pumping at 300 gpm is shown in Figure 5.4. Given the average values of S and T calculated from the Wehran test, either system will provide one foot of drawdown along the assumed boundary of the contaminated zone within one week of the initiation of pumping. The three well system will provide greater assurance that contaminants will not migrate downgradient of the groundwater recovery zone.

The proposed decontamination well design is not expected to influence groundwater rechange and supply to wells around Tennants Pond. Groundwater flow modeling on a regional scale would provide important information on the effects of the proposed remedial actions on flow within the Pricketts Brook watershed and the adjacent watersheds.

DISCUSSION

Based on the alternative design evaluation for the decontamination well system the NJ DEP preliminary design appears reasonable. Both of the pump rates suggested above (300 gpm for a single well and 480 gpm for a three well system) are lower than the minimum discharge rate proposed by Dames and Moore. The three well decontamination well system will provide greater assurance that contaminants will not migrate downgradient of the groundwater recovery zone. A greater pump rate would accelerate the rate of decontamination, but the extent to which the duration of pumping could be reduced was not evaluated.

A rough estimate of the downgradient extent of the contaminant plume is shown in Figure 5.2. The estimated boundary is just beyond the downgradient side of the alternative design for the slurry wall shown in Figure 4.1. The alternative wall design may, in fact, enclose the entire contaminated area, with the exception of sediments in Pricketts Pond downgradient of the wall. Although the available information is not sufficient to make a final determination, the downgradient extension of the wall may eliminate the need for decontamination wells outside of the slurry wall.

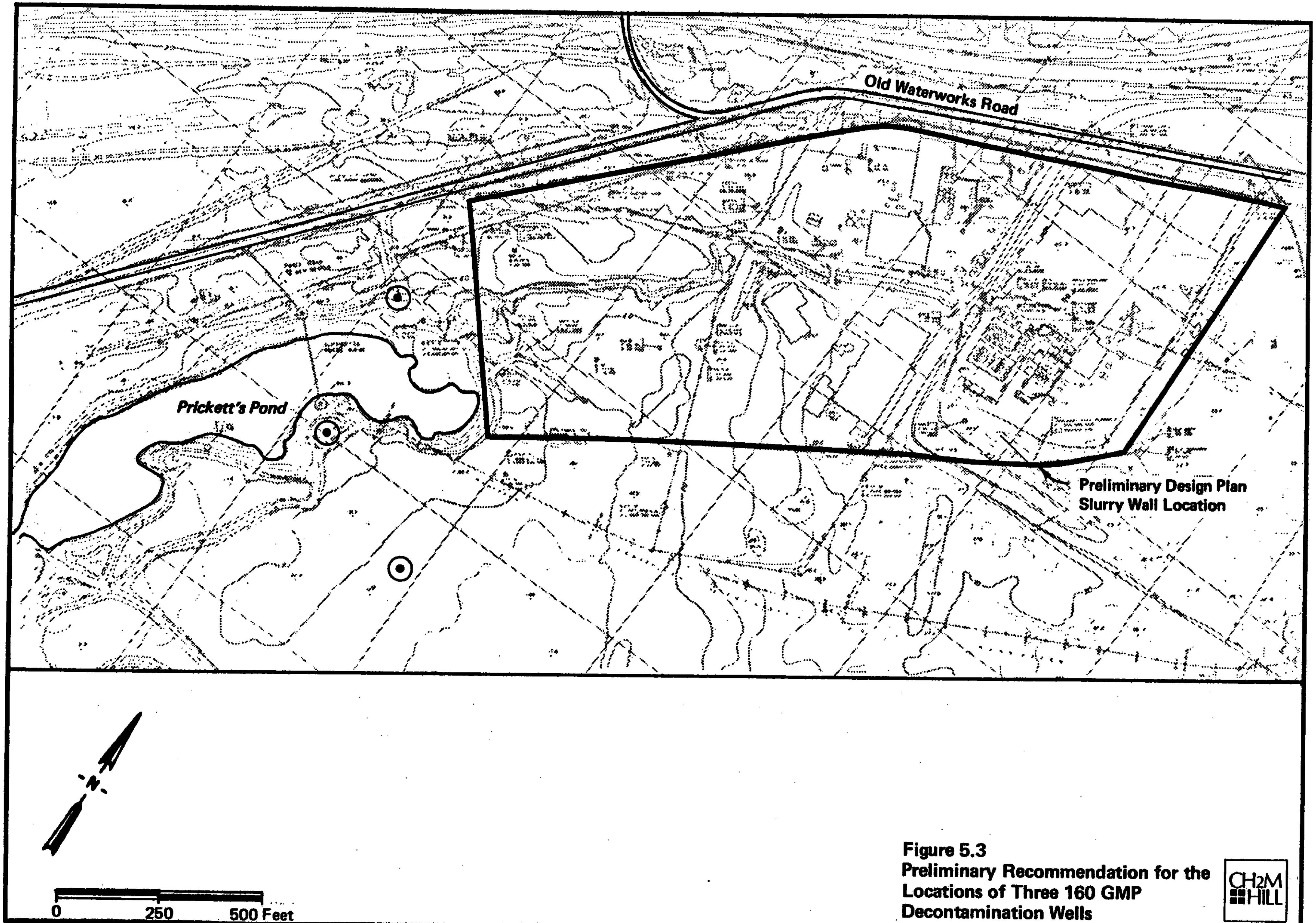

Figure 5.3
Preliminary Recommendation for the Locations of Three 160 GMP Decontamination Wells

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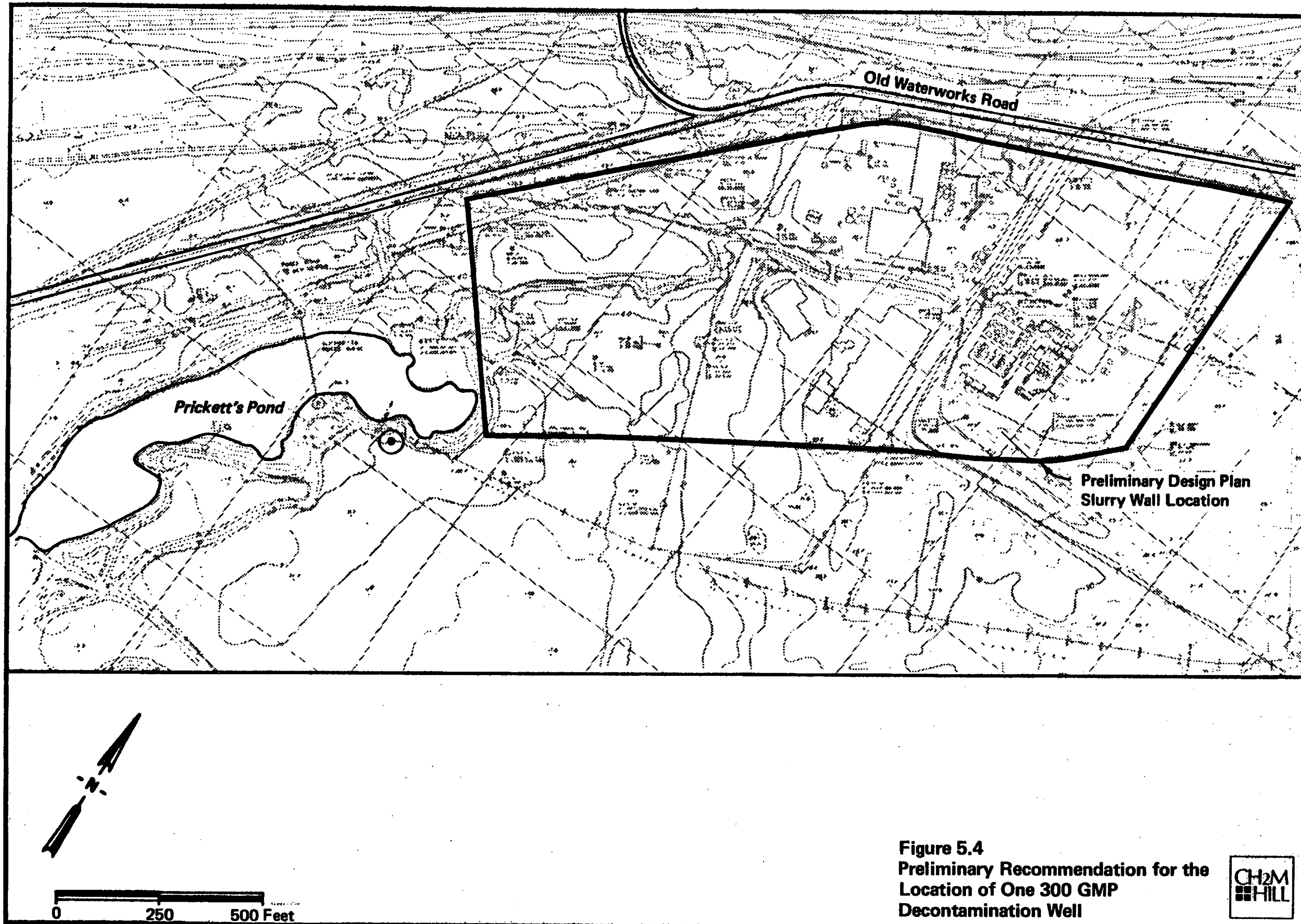

Figure 5.4
Preliminary Recommendation for the Location of One 300 GMP Decontamination Well

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In terms of general design criteria, decontamination wells should be screened through the entire depth of Old Bridge Sand Aquifer. Partially penetrating wells may not intercept contaminants that are below the screened interval.

It is important to note that neither the extent of the contaminant plume nor the hydraulic properties of the aquifer are adequately defined at this time to undertake a detailed design for the decontamination wells.

CONCLUSIONS AND RECOMMENDATIONS

The information on the areal distribution of contaminants is incomplete. It is possible that the contaminant plumes extend beyond the southern and south eastern extent of the monitoring well network and north and northwest of the CPS/Madison properties across Old Waterworks Road. General locations for new wells should be southeast of Pricketts Brook , south of the CPS/Madison facilities, and north and west of the facilities across Old Waterworks Road. These wells should be installed in the Old Bridge Sand Aquifer.

The continuity and hydraulic properties of the aquiclude below the Old Bridge Sand Aquifer are not adequately characterized. Groundwater samples from one new well developed in the Sayreville Sand should be collected and analyzed in order to determine if contaminants have moved through the aquiclude into the Sayreville Sand. Water levels should be measured in the Sayreville Sand to quantify the vertical hydraulic gradient. A pump test should be run in the Sayreville Sand using observation wells in the Sayreville and in the Old Bridge Sand in order to evaluate the leakiness of the aquiclude that separates these units. In addition, at least two other piezometers should be installed in the Sayreville Sand to estimate the direction of groundwater movement within that aquifer.

The preliminary design recommendation for a decontamination well system consists of three wells discharging at 160 gpm each. Proposed locations for these wells are shown in Figure 5.3.

The results of a pump test in the Old Bridge Sand Aquifer revealed considerable heterogeneity in the hydraulic properties of the formation. In order to have sufficient data for final design of the decontamination well system, a pump test in the Old Bridge Sand Aquifer should be conducted with the pumped well and observation wells in the area where the decontamination wells are likely to be installed. The pump test well may be suitable for continued use as a decontamination well.

Regional and site-specific flow models are required in order to evaluate the effectiveness and to optimize the design of the complete remedial plan. The regional flow model will be used to evaluate general recharge, discharge, and flow patterns in the Tennent Brook watershed. The current data base is adequate to run the regional model. A site-specific model will be used to determine the effectiveness of various well locations, discharge rates, brook relocation, surface water management, and slurry wall configuration.

Two additional stratigraphic borings are needed along the route of the proposed east boundary of the slurry wall as described in Section 2. The results of these borings will be used to determine seepage through the slurry wall in addition to checking for the presence of the South Amboy Fire Clay.

Proposed locations of borings for stratigraphic confirmation, water quality wells, and pump test wells are shown in Figure 5.5. Descriptions of the borings are given in Table 5.2.

As stated above, if the alternative recommended location for the slurry containment wall is used, it may not be necessary to install decontamination wells outside of the containment wall.

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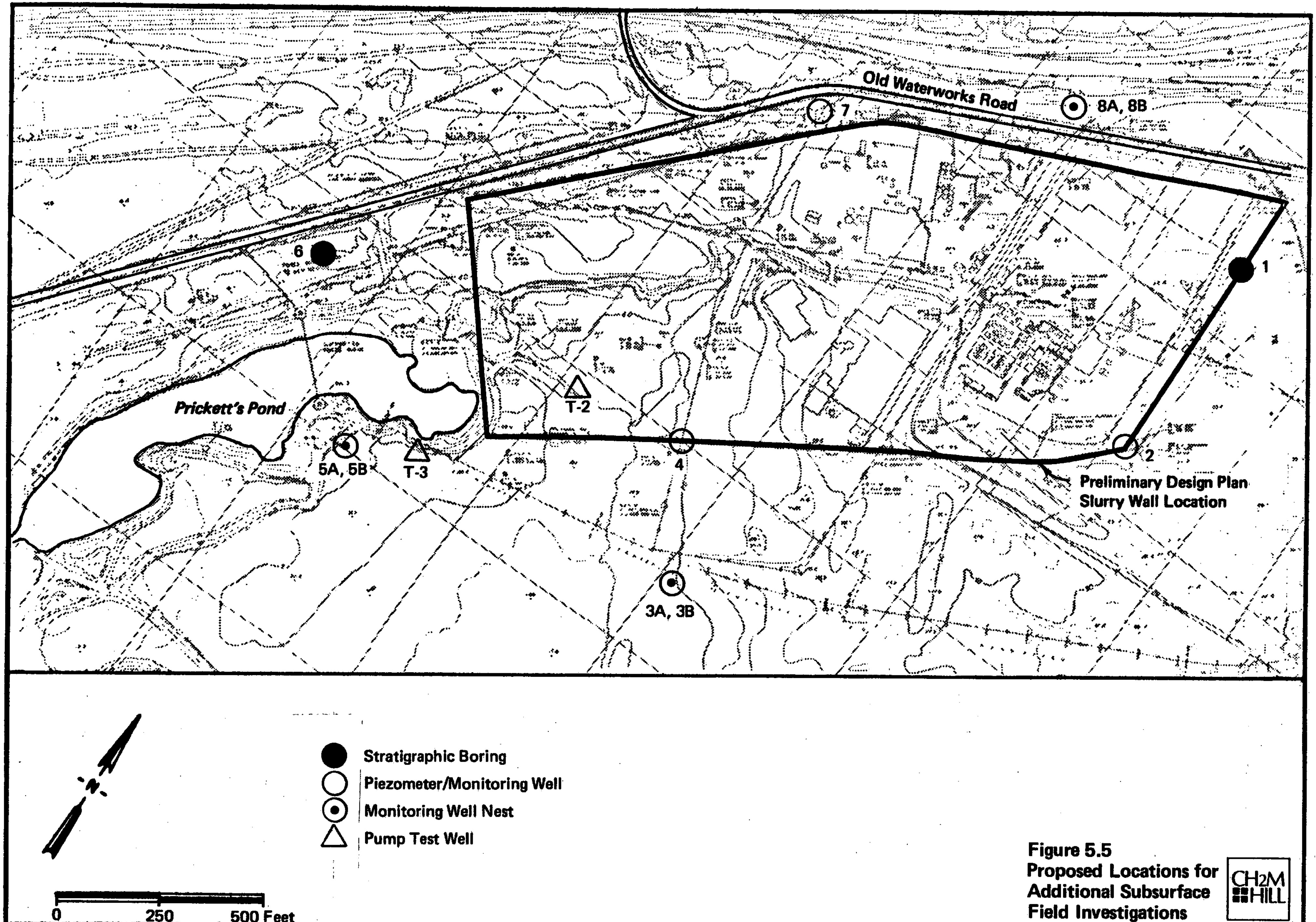

Figure 5.5
Proposed Locations for Additional Subsurface Field Investigations

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Table 5.2
DESCRIPTIONS OF PROPOSED ADDITIONAL FIELD INVESTIGATIONS

Borehole No.	Purpose (Type)	Depth
1	Stratigraphic Confirmation	5' below the top of the Fire Clay
2	Stratigraphic Confirmation and Piezometric Levels in the Sayreville	15' below the top of the Sayreville or 2' below the bottom of the Sayreville Sand (whichever is shallower)
3A, 3B	Groundwater Quality Wells	±30', ±75'
4	Piezometric Levels in the Sayreville	15' below the top or 2' below the bottom of the Sayreville Sand (Whichever is shallower)
5A, 5B	Groundwater Quality Wells	±30', ±75'
6	Stratigraphic Confirmation	5' below the top of the Fire Clay
7	Piezometric Levels in the Sayreville	15' below the top or 2' below the bottom of the Sayreville Sand (Whichever is shallower)
8A, 8B	Groundwater Quality Wells	±35', ±75'
T-2	Pump Test Well	2' below the bottom of the Sayreville
*T-3	Pump Test Well	2' below the Old Bridge Sand-Fire Clay Interface

*This well may be suitable for use as a decontamination well.

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Section 6
HEALTH AND SAFETY ISSUES

Section 6
HEALTH AND SAFETY ISSUES

INTRODUCTION

This section describes approaches which should be used to protect the health and safety of workers performing site investigations or remedial measures. It also addresses public health considerations, particularly of nearby workers at the two facilities. Health protection begins with recognition of actual or potential hazards.

GENERAL

For this site, the data are fairly well developed and we know that there are volatile and nonvolatile organic compounds in the groundwater, soils and sediments and that there are also elevated metal levels. The potential for contamination by all substances known or suspected to be on site should be evaluated. Other hazards to evaluate include physical, biological and ergonomic factors which might contribute to injury, additional stress on the worker, or extreme discomfort and impaired efficiency. Physical hazards include radiation; rough terrain or uneven footing; working near or in large bodies of water; and climate, including heat, extreme cold and storms. Ergonomic stresses include discomfort, heat stress, and impaired efficiency attributable to the use of personal protective clothing and devices. Biological hazards include recognition of poison ivy and other plants, as well as insects and other animals.

The initial step involves a detailed review of the site history and all sampling and analytical data. This review is to identify and quantify chemical hazards, as well as physical and biological hazards. For example, air quality measurements are very useful in assessing the need for and type of respiratory protection for workers. Knowing the soil and water contaminants enables a better selection of appropriate dermal protection, including coveralls, boots, and gloves as well as respiratory protection. Knowledge of contaminant identities is also critical in the selection of monitoring strategies and instrumentation.

Evaluation of recognized potential hazards begins at the planning stage and continues through the site work and may not end for months after completion of the project. Evaluation includes both measurement of hazards and assessment of their risk potential. During the planning stage, recognized potential hazards, such as chemical contamination, are assessed for their potential exposure routes to workers and their toxicity. Compounds which pose an exposure threat and which have been identified as toxic must be controlled. The degree of control required is determined by consulting the Threshold Limit Values (TLVs) and the OSHA Permissible Exposure Limits, as well as the literature on toxicity. Potential synergistic effects of mixtures of compounds are also considered when permissable exposure levels are determined.

Monitoring is essential to measure potential worker exposures and to evaluate the effectiveness of controls. Controls may include engineering controls, such as ventilation, isolation of hazardous materials from workers, reduction of the amounts of material exposed, dust suppression, etc. Other controls include administrative or work practice controls such as decontamination procedures, contaminant avoidance, upwind worker positioning, limiting the work shift duration in order to decrease exposure and increase recovery time, selection of medically fit workers, and training in hazard recognition, evaluation, avoidance and control. Controls which provide personal protection require knowledge of the hazards to the worker in order to select appropriate dermal and respiratory protection.

EPA has identified 4 generic levels of personal protection. Each level has many variations, the selection of which should be made by a trained professional. Level D is the basic work uniform consisting of boots with steel toes and shanks, cotton coveralls or work clothes, safety glasses and a hard hat. Specifications for neoprene boots, disposable booties, disposable outer coveralls or rain suits, a wide variety of glove materials and a 5-minute suppled air escape pack may be added. Level D is worn when there is no respiratory hazard. The 5-minute escape pack may be specified to use in the event of a sudden chemical release. Level C offers the same choices of dermal protection, but upgrades respiratory protection to include an air purifying respirator. Selection of the respirator must be based upon knowledge of airborne chemical or physical hazards in order to select the appropriate cartridges or canisters. Level B supplies the ultimate in respiratory protection, i.e., a supplied air respirator and offers considerable flexibility in selecting dermal protection. Level A is the ultimate in both dermal and respiratory protection using a self contained breathing apparatus and a fully encapsulated suit, the so-called moon suit. Level A is rarely required and its use is generally limited to confined space entry or work with high concentrations of extremely toxic substances.

The use of protective clothing and devices sometimes creates its own hazards. Chemically protective clothing, for example, promotes the onset of heat stress because body heat is contained by the suit. The weight of self contained breathing apparatus may contribute to fatigue, communications are hampered by the use of respirators and vision is narrowed by the respirator facepiece design.

Each work activity on or near the CPS/Madison site requires a thorough evaluation of these factors to develop a site safety plan which outlines the tasks to be performed, describes the site characteristics and hazards, evaluates the hazards, specifies medical and training specifications and other staffing requirements, prescribes monitoring and control measures, describes decontamination procedures, and specifies emergency response procedures.

Common to each of the site investigative and remediation activities is the hazard of exposure to toxic volatile organics and toxic metals. All personnel assigned to work on this program should be medically examined to determine their ability to perform their tasks on a hazardous waste site, including use of a respirator. At a minimum, each team member must be trained in the use of the protective equipment, including respirators, in standard operating procedures, and in the provisions of the site safety plan. Supervisors should be experienced in hazardous waste site operations and have undergone formal classroom training in hazard recognition and assessment. Each work party should be under the direct observation of a site safety coordinator who is responsible for implementing the site safety plan.

The EPA Interim Safety Operating Guides (September 1982) should serve as the model of standard good practice for all work on this program. Application of these approaches to health and safety to the 4 task areas listed below are presented in the discussion which follows:

- onsite supplemental services
- realignment of Pricketts Brook
- installation of slurry cutoff wall
- installation of decontamination, maintenance and monitoring wells.

ONSITE SUPPLEMENTAL SERVICES DURING ADDITIONAL SITE INVESTIGATIONS

The first consideration is identification of the specific tasks to be performed, i.e., soil borings, test pit excavations, pump tests, well installation and monitoring, and topographic surveys. Each of these activities poses unique exposure hazards, both to team members and to nearby populations. Topographic surveys for example, pose no foreseeable hazard to nearby populations and minimal hazard to team members. Continuous air monitoring by a qualified site safety coordinator would be a minimum requirement to measure total organic vapors in the air. If the measured levels were at background, Level D would be prescribed. If, however, organic vapor levels exceeded background, Level C would be called for. Personnel entering the site should be medically certified to perform work on hazardous waste sites and to wear a respirator. In addition, training in standard operating procedures for hazardous waste site work must be provided to all team members. All workers should be warned of the known hazards.

Any activities which involve disturbing the soil surface increases the potential for exposure to contamination, both by skin contact or absorption or by respiratory exposure. In order to reduce the hazards of such potential exposures, protective clothing should be required. Continuous monitoring of breathing air quality by an organic vapor monitor is necessary to determine the need for respiratory protection. The EPA Interim Standard Operating Safety Guides recommend the use of Level C whenever organic vapor concentrations in air exceed background by up to 5 ppm. Above this criterion, Level B is recommended. Selection of the proper monitoring instrument is critical. In particular, the monitoring instrument must be sensitive to the types of volatile organic compounds that may be encountered. The site safety plan for each activity must recommend specific monitoring instrumentation.

A decontamination facility must be set up prior to any site entry. The site safety plan must specify the arrangement of this facility for each task. The disposal of investigation derived material, such as used protective clothing, decontamination solutions, etc. must be determined prior to startup.

Emergency information, such as telephone numbers, maps to the nearest emergency room, and first aid equipment should be specified in each plan.

PRICKETTS BROOK REALIGNMENT

Preparation of a new stream bed will be almost entirely offsite, through an area believed to be non-contaminated. As such, the health and safety plan should call for continuous organic vapor monitoring and dust suppression during excavation, but the level of personal protection required is anticipated to be Level D. All the material will be medium to coarse sands, so dust should not be a problem. Steel toe boots, hard hat, and eye protection should be mandatory. The monitoring will serve to alert the site safety coordinator of conditions which may require upgrading to Level C. Monitoring should include both the excavation area and the breathing zone area of workers. If elevations in organic vapor levels emanating from the soil are detected, then workers must exercise caution to remain upwind and at some distance from that soil to the extent possible. Continuous breathing zone monitoring will then be used to determine the need for respiratory protection. The response to any elevation in organic vapor level over background should be to upgrade personal protection to Level C, including an organic vapor air purifying respirator and dermal protection. If organic vapor levels exceed 5 ppm over background, then the workers must either upgrade to Level B or evacuate the area.

During the onsite work phase of the realignment, dermal protection, consisting of neoprene boots, disposable tyvek coveralls, and impermeable gloves should be worn because of the possibility of contact with contaminated soil or water. Continuous monitoring should be used to determine the need for respiratory protection. Whenever there is the potential for water to splash on a worker, that worker should be provided either coated tyvek coveralls or a splash apron.

If this work is conducted in hot weather, i.e., warmer than 70°F, then heat stress monitoring should be performed by the site safety coordinator.

Prior to commencing work, a decontamination facility must be set up, in case contamination is discovered. Regardless of measured organic vapor levels, each worker on this task should be required to wash hands and face, at a minimum, before taking a break or leaving the work area. Construction vehicles should be job dedicated in order to eliminate the need for vehicular decontamination until completion of the realignment. All vehicles and construction equipment used in handling soil will need to be steam cleaned, but careful traffic control may eliminate or reduce the need to decontaminate supply trucks and other non-soil contacting vehicles. Nonconstruction vehicles should be directed to clean areas only.

Management and disposal of excavated soil will depend upon analysis to determine whether or not it is a hazardous waste. If organic vapors are released from excavated soils, then these soils must be isolated from workers and the general public in order to prevent exposure. The use of gloves should be mandatory for any soil handling, regardless of organic vapor levels, because of the possibility of metals contamination.

Disposal of used disposable protective clothing and respirator cartridges, as well as decontamination solutions must comply with RCRA and State regulations.

SLURRY CUTOFF WALL

The slurry cutoff wall is considered "onsite" for the purposes of planning work practices related to health and safety. In practical terms, this means that all personnel, equipment and vehicles must undergo decontamination prior to leaving the site and that all personnel working on this wall should be medically certified for respirator use and trained in hazardous waste site procedures.

Most of the proposed location of the slurry wall is outside the areas of high contamination. Much of the installation can reasonably be anticipated to be conducted with Level D protection. Steel toe, steel shank neoprene boots, cotton work clothes, safety glasses and hard hats are minimum personal protection measures. Near Pricketts Pond, the risk of exposure to organic and metal contaminants increases and the level of personal protection should increase accordingly. Work in wet areas near the pond should be performed with dermal protection consisting of disposable tyvek coveralls or rain suits and impermeable gloves. Work in and immediately adjacent to Pricketts Pond should require thorough splash protection, including a face shield, if a full face respirator is not worn. Also, safety lines and life preservers should be required for all work around or in the pond.

Because the operation is wet, dust is unlikely to be a problem at the construction site. However, the removed soils and sediments must not be permitted to become a dust source. Dust from these soils may contain elevated levels of toxic metals and organic chemicals.

Continuous organic vapor monitoring is required throughout the slurry wall installation. An explosimeter is also required. Readings from the organic vapor monitor are to be used to determine the level of protection for workers. It is likely that the area around Pricketts Pond may release vapors when the soil is disturbed. Also, the excavated soils and sediments have the potential for vapor release. If total organic vapor levels are measured above background, then respiratory protection should be required. The possibility of organic vapor levels exceeding 5 ppm exists and should this situation develop, an immediate evacuation should be made and work should not be allowed to continue unless supplied air respirators are worn by workers.

The excavated materials should be deposited downwind of the work site and access to this material should be limited. If organic vapors are being released, this material should be either immediately removed to a licensed hazardous waste facility or covered with an impermeable membrane cap or at least 6 inches of dirt.

The State may impose and enforce emission standards to protect nearby populations, even if the pile does not threaten the health of the remediation workers.

A decontamination pad will be required prior to work startup. Personnel decontamination, at a minimum, should consist of a boot and outer glove wash and rinse, removal of boots and outer gloves, removal of outer protective clothing, respirator removal, inner glove removal, and a hands and face wash. Workers should be provided with a protected area onsite to change back into street clothes. Clothing worn onsite should be laundered (on-site) daily.

WELL INSTALLATION

Well installation, particularly the groundwater recovery wells within the cutoff wall, poses the highest risk of exposure to workers of the planned remedial actions. The recovery wells will be located in areas of known volatile organic substance contamination. The selection of monitoring and personal protection strategies is critical here because of the presence of at least 14 organic compounds, some of which are recognized or suspected human carcinogens. The major component is methylene chloride, a common solvent which as been the object of several recent toxicologic studies. The OSHA Permissible Exposure Limit is 500 ppm, however, the Threshold Limit Value (TLV) is 100 ppm. This level would not be expected to be exceeded under any planned site activities. Monitoring for methylene chloride requires either a flame ionization detector, such as the OVA, or photionization detector (PID) with an 11.7 eV lamp. This higher energy PID lamp presents some operational difficulties not experienced with the more commonly used lower energy lamps, i.e., 10.2 eV. Without the higher energy lamp however, methylene chloride, chloroform and carbon tetrahcloride vapors would not be detected. Some quantified organic compounds in the groundwater are considerably more toxic than methylene chloride. For example, Dames and Moore (1980) reported concentrations of 1,1,2,2-tetrachloroethane in groundwater as high as 8.4 ppm. The TLV is 1 ppm and it is dermally active, that is, it can be absorbed through the skin. At a minimum, dermal protection for drillers should be required.

Drilling in Level C with organic vapor cartridges is recommended for all onsite well installation, regardless of organic vapor measurements. The possibility of encountering volatile organic contamination remains high throughout the entire drilling operation. If vapor levels in excess of 5 ppm above background are encountered drilling should be immediately halted and then resumed in Level B.

Installation of the monitoring wells outside the slurry wall area may be conducted in Level D if organic vapor levels do not exceed background. As a precaution, drillers should wear steel toe, steel shank neoprene boots, tyvek or other protective outer garments, neoprene or nitrile gloves with disposable surgical inner gloves, hard hats and eye protection. Air purifying respirators should be immediately available if monitoring detects elevated organic vapor levels.

All drilling should be continuously monitored with an explosimeter. A reading of 50 percent of the lower explosive limit (LEL) is an action level for immediate evacuation. Readings above 20 percent LEL require extreme caution in proceeding.

Decontamination of equipment and personnel must be planned and in place prior to work startup. All drilling equipment will require decontamination by detergent and water wash and rinse, methanol rinse, water rinse and steam cleaning. Level C protective gear is required for equipment decontamination. Personnel decontamination should follow the standard procedures for Level B or Level C decontamination.

Warm weather work entails planning a heat stress monitoring protocol for drillers. The site safety coordinator should conduct frequent safety meetings and emphasize the importance of heat stress prevention. Planning for work/rest cycles, water breaks, personnel monitoring and emergency response should be spelled out in the site safety plan.

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Section 7
CONSTRUCTION COST AND SCHEDULE

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ESTIMATED CONSTRUCTION COST

An order-of-magnitude construction cost estimate was prepared based on the recommended modified alignments and construction of the Pricketts Brook channel, slurry containment wall, and the groundwater recovery wells.

An order-of-magnitude cost estimate is an approximate estimate made without detailed engineering data. It is normally expected that an estimate of this type would be accurate within +50 percent and -30 percent, in accordance with the categories established by the American Association of Cost Engineers. The estimate has been prepared through exercise of our experience and judgment in applying presently available cost data and conceptual design elements and represents our opinion of probable construction costs. It is recognized that CH2M HILL has no control over the factors affecting the final costs, and therefore cannot warrant that the project costs will not vary from this estimate. Actual costs will depend on actual labor and material costs, competitive market conditions, final project scope, implementation schedule, and other factors at the time of construction.

The construction cost estimate is summarized in Table 7.1. The following assumptions were made in developing the unit prices and quantities for construction.

1. Health and safety levels of protection affect the productivity of the construction contractor. For most of the site, level "C" protection was assumed to be appropriate; for the area near Pricketts Pond, level "B" protection was assumed.

2. All costs are presented in August 1984 dollars with no adjustment for inflation through the construction period.

3. No operation, maintenance, or treatment costs are included.

4. It has been assumed that no decontamination wells will be installed. Three maintenance wells and ten monitoring wells have been included.

SEQUENCE OF CONSTRUCTION

The implementation of the various remedial action plan elements, including the brook realignment, slurry

Table 7.1
ORDER-OF-MAGNITUDE
CONSTRUCTION COST ESTIMATE
SUMMARY

1. Brook Realignment	
Clearing and grubbing	$ 3,100
Excavation and grading	57,200
Topsoil, seeding, mulching	89,400
Erosion protection	110,000
New Jersey allowance (5%)	13,000
Mobilization (10%)	26,000
Health and safety (12%)	31,200
Subtotal	329,900
Contingency (15%)	49,500
Total	$ 379,400
2. Slurry Containment Wall	
Clearing and grubbing	$ 5,000
Dike construction	90,500
Soil-bentonite wall	4,111,200
Concrete wall	411,800
Cover, topsoil and seeding	231,500
Sewer and railroad crossings	34,000
New Jersey allowance (5%)	244,200
Mobilization (10%)	488,400
Health and safety (12%)	586,100
Subtotal	6,202,700
Contingency (15%)	930,400
Total	$7,133,100
3. Groundwater Recovery Wells	
Access road	$ 800
Drilling and casing	5,800
Header piping	30,000
Pump testing	12,000
Monitoring wells	18,000
New Jersey allowance (5%)	3,300
Mobilization (10%)	6,700
Health and safety (12%)	8,000
Subtotal	84,600
Contingency (15%)	12,700
Total	$ 97,300

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containment wall construction, and groundwater recovery (maintenance) well installation, involves critical construction sequencing.

The realignment of Pricketts Brook must precede construction of the slurry wall across the existing channel. If the channel were constructed too late, construction of the slurry wall across the existing channel or Pricketts Pond would be delayed. Either flooding of the plant sites or continued discharge of contaminants into Pricketts Pond would result. However, if the channel were dredged too soon, contaminated groundwater might be redirected to the southeast toward the new channel. This would increase the potential for contaminants to migrate outside of the slurry wall and for the new channel to become contaminated either through groundwater discharge into the new channel or through contaminated surface water runoff into the new channel.

Upgradient portions of the slurry containment wall can be constructed during the progress of the brook realignment. It is advantageous to construct the upgradient portions prior to the downgradient portions to reduce the volume of groundwater to be recovered by the maintenance wells.

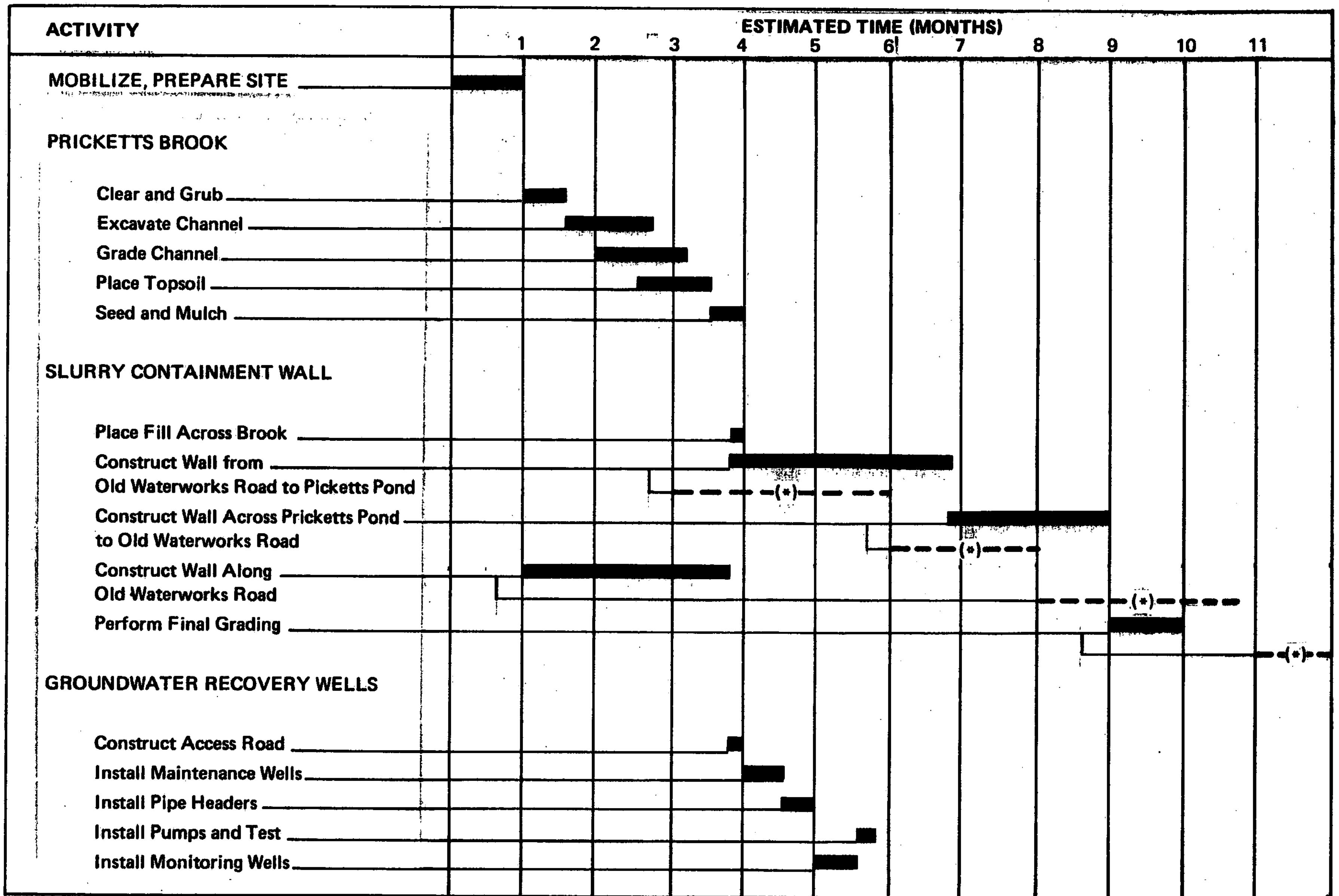
The maintenance wells must be installed and must be operational before the downgradient portion of the slurry wall through Pricketts Pond is completed. Otherwise, the slurry wall would create a "damming" of the groundwater with subsequent flooding of the lower reaches of the site.

The groundwater monitoring wells should be installed prior to conducting pump tests of the groundwater maintenance wells so that the monitoring wells may serve as observation wells.

The sequence of construction along Old Waterworks Road should be closely coordinated or phased to minimize adverse impacts on the C.P.S./Madison plants. The excavation should not extend more than about 100 feet in advance of the concrete backfill placement so that the duration of disruption of the site access can be minimized.

ESTIMATED CONSTRUCTION SCHEDULE

An estimate of the probable duration of construction activities is summarized in Figure 7.1. The estimated construction schedule was developed based on expected rates of productivity and experience on similar projects. The schedule reflects the sequence of construction described above. No delays due to adverse weather, seasonal constraints, or other unforeseen circumstances have been included in the schedule shown. The schedule also does not



(*) Indicates estimated schedule if slurry wall built after creek alignment is complete.

Figure 7.1
Estimated Construction Schedule

CH2M HILL

reflect construction of a groundwater treatment system or force main to the Middlesex County Runyan Pumping Station.

If construction of the upgradient portion of the slurry wall is begun at the same time as the brook realignment, the construction is expected to last approximately 10 months. If the wall construction is postponed until after the new channel realignment has been substantially completed, then construction is expected to take an additional two months.

Operation and maintenance of the groundwater recovery system must commence prior to completion of the downgradient portion of the slurry wall and will continue indefinitely. This operation and maintenance is not shown on the construction schedule.

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APPENDIX A

A.1 C.P.S./MADISON PROJECT DOCUMENT SUMMARY
A.2 C.P.S./MADISON DOCUMENT CHRONOLOGY

APPENDIX A1
Project Document Summary

Document Control Number	Title or Description/Author/Date	Chronologic Sequence No
1.	Feasibility and Advisability of Containment and Removal of Contaminated Groundwater and Soils; Dames and Moore; August, 1980. [Major Report; Engineering/ Design/Data].	17
2.	Sediment Sampling and Heavy Metals Analysis, Pricketts Pond, Converse Consultants; April, 1984. [Data].	69
3.	Comments of clean-up scheme proposed (by) Dames and Moore of C.P.S./Madison Industries Site, Middlesex County, NJ DEP, Div. Water Resources; includes cost estimates for the recommended cleanup strategy. Undated (1981?). [Engineering/Design].	30
4.	Same as Doc. No. 3, includes analysis of deeper slurry wall, and updated assumptions and calculations.	31
5.	Review of Dr. Douglas report on Prickett's Pond sediments and metals solubility; Memo from John Slaughter (NJ DEP) to Haig Kasabach; 11/26/80. [Engineering/Design].	18
6.	Well sampling, CPS, Inc., Old Bridge Township; Memo from Charles Maack, NJ DEP, to Eric Peterson and John Tomasiello, Region II; Sampling 5/19/81; memo dated 5/22/81. [Data/Results].	23
7.	Stream bed sampling of Prickett's Brook, C.P.S./Madison Chemical, Inc., Old Bridge Township. Memo from Maack and Tomasiello, NJ DEP, to James Mumman; Sampled 6/4/81; Memo dated 6/5/81. [Data/Results].	24
8.	Memo on State v. SPS, et al. Docket No. C-4474-76, Court Order of 10/16/81 (Doc. No.20), from Steven Gray, NJ Dept. Law and Public Safety, to Arnold Schiffman, Director, Division of Water Resources; Memorandum dated 11/10/1981. [Legal].	29

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Title or Description/Author/Date

Document Control Number		Chronologic Sequence No
9.	NJ DEP News: DEP wins precedent setting groundwater pollution suit; 7/10/81. [Background; Legal].	26
10.	Rationale for why Middlesex County Utilities Authority requested treatability studies of well waters in Runyon Watershed proposed for discharge to MCUA treatment system; from Robert Rowe, Chief Chemist, MCUA, to William Honachefsky, NJ Division of Water Resources; 4/7/1982. [Data/Results; Engineering].	34
11.	Critique of C.P.S./Madison Addendum 2: Wehran Engineering's proposal for site remediation. Addresses limits of the monitoring system and flaws in plume mapping. Memo from Dan Toder (through) William Brown and John Trela, NJ DEP, to Paul Harvey, Central Region Enforcement; 4/24/1984. [Engineering/Design].	68
12.	Figure: Movement of zones of Methylene Chloride (mg/l or ppb) concentrations in Groundwater From 1977 to 1979; NJ DEP; Undated. 1980? [Data/Results].	19
13.	Figure: Movement of zones of lead (Pb) Concentration in Groundwater from 1975 to 1979, NJ DEP; Undated. 1980? [Data/Results].	20
14.	Draft Preliminary Specifications C.P.S./Madison Sites NJ DEP; These specification accompany plans. Includes boring logs, gamma logs, and grain size analysis of samples from borings along the proposed route of the slurry wall. 2/1983 [Engineering/Design; Data/Results].	28
15.	AdTek report to the City of Perth Amboy on contamination of the Old Bridge Aquifer; Title not available; 3/75; [Major Report; Data/Results].	3
16.	Draft Report. Treatability Study of Groundwater from the Madison Industries and C.P.S. Chemical Co. Properties	45

Document Control Number	Title or Description/Author/Date	Chronologic Sequence No
	in Old Bridge Township, NJ. Prepared by Princeton Aqua Science (PAS) for NJ DEP; 5/83. [Major Report; Engineering; Data].	
17.	Final from PAS; 9/83.	55
18.	Recommended Remedial Program for Abatement of Ground-Water Contamination of the Old Bridge Sand Aquifer in the Vicinity of C.P.S./Madison Industries; Wehran Engineering; 5/3/83. [Major Report; Engineering/Design].	42
19.	Addendum to Wehran Engineering Report; 6/21/83. [Engineering/Design].	46
20.	Addendum Number Two to Wehran Engineering Report; 3/28/84.	67
21.	City of Perth Amboy, Plaintiff, v. Madison Industries, Inc., Defendant, and State of NJ DEP, Plaintiff, v. Chemical and Pollution Sciences, Inc, et al. (Consolidated) Docket No. C-4474-76 Civil Action Final Order and Judgment; 10/16/81 [Legal].	28
22.	Hazardous Materials Intelligence Report, Listing CPS/Madison as one of 11 sites on the NPL in a joint appeal against EPA-challenging their inclusion on the NPL; 2/3/84.	63
23.	Well Record, NJ DEP, Div. W.R., CPS Chemical Well No. 1, off Bordentown Ave. Owner's Well No. 1, Industrial Use, 68 feet deep, screened 56-66, drilled by Layne, Permit #29-8-130, 5/23/75. As above, 75 feet deep, screened 56-66, Permit #28-7587; 7/25/72. Note: Both wells are designated Well No.1. [Engineering].	4
24.	Well Record, NJ DEP, Div. WR, Madison Industries Well No. 1, Observation Well, 42 Feet deep, screened 17-37, drilled by R&G Endreson, Permit 29-8001; 7/25/75.	6

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Document Control Number	Title or Description/Author/Date	Chronologic Sequence No
	Well Record, Well No. 2, 42 Feet deep, Screened 17-37, Permit No. 29-8002; 7/27/75. [Engineering].	
25.	Perth Amboy Well Field Water level measurements. Includes wells 3, 4, 5, 11, 16, G, F, E, D, A, #6, B, C, MI #1, MI #2, MI #3, MI #4, MI #5, CPS #1, CPS #2, CPS #3; 11/28/78. [Data/Results].	14
26.	Well Logs, City of Perth Amboy, Permit No. 28-225, Layne Well #3, Public Supply, 68 ft. deep, screened 48-68', drilled by Layne-New York Co.; 3/14/51. Layne Well No. 4, Permit No. 28-1623, 68'7" deep, screened 51'7"-66'7" Completed 7/1/55. Layne Well No. 5, Permit No. 28-5574 80' deep, screened 50-80'; 9/14/65. [Engineering].	1
27.	Water table elevation data from 32 Wells (some well nests), Author unknown (Woodward-Clyde?); Includes map of locations; 3/24/82. [Data/Results].	33
28.	MI/CPS Treatability Study, Temperature; pH, specific conductance of sample composited from Wells MI-3, BSL-11, T-1; Memo from Chris Schiller to William Honachefsky; 2/9/83. [Data/Results].	39
29.	Water analysis data, MI-3 (metals), MI-3 (again?) (metals & VO Scan), T-1 (metals and VO Scan), BSL-11 (metals & VO Scan). Metals data from two MI-3 analyses different. Bottle No. 02238 appears to be EP-TOX Extraction; 2/7/83. [Data/Results].	38
30.	Evaluation of alternative designs for relocating Pricketts Brook, NJ DEP Div. Water Resources, memo from John H. O'Dowd to John W. Gaston; 8/16/83. [Engineering/Design].	51

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Project Document Summary

Title or Description/Author/Date

Document Control Number	Title or Description/Author/Date	Chronologic Sequence No
31.	Memo on construction of S1-S2-S3 wells, from Richard Dalton to Jim Mumman; 2/25/81. (Note: refers to earlier memos from Dalton to Honachefsky, 10/3/77 (soil logs) and from Schiller to Files, 10/21/77 (Construction)). [Engineering/Design].	21
32.	Volatile organic air sampling results from first manhole below C.P.S./Madison Industries, Samples H28F-82 (Ambient Air) and W287-82 A, B, & C (3 x 8-hour samples). Collected by Chris Schiller, Analyzed by NJ DOH Environmental Chem Labs; 9/1/82. [Data/Results].	35
33.	Cover letter for Preliminary Design Plans for C.P.S./Madison remedial action; from W. Honachefsky, Project Manager, to J.W. Gaston, Jr., Director of NJ DEP. Addresses need for immediate implementation of slurry wall installation and stream rerouting, plus need for final decisions/actions concerning pretreatment, dredging of pond, air scrubbers, location of decon./maintenance wells. Refers specifically to responsibility of City of P.A. for dredging; 2/22/83. [Background; Engineering/Design].	40
34.	Engineer's Report for Madison Industries - Design of Proposed Widening of Pricketts Brook to Accommodate Proposed Madison Industries expansion; 7/75. [Engineering].	7
35.	Newspaper Article on progress of cleanup for C.P.S./Madison in the Star-Ledger, by Anita Susi. Brief Summary of legal and technical issues and the roles and positions of State, City of P.A., and industry; 3/3/83. [Background;Legal].	41
36.	Results of sanitary sewer sampling upstream and downstream of C.P.S./Madison Industries; data transmitted from Charles Maack, NJ DEP to Joe Romash, C.J.Kupper; Sampled 3/11/82; Memo date 9/24/82. [Data/Results].	32

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Project Document Summary

Document Control Number	Title or Description/Author/Date	Chronologic Sequence No
37.	Toxic Pollutants and US EPA Ambient Water Quality Criteria - Data to assist in regulatory and enforcement activities, memo from John Trela, F. Markewicz, and H. Kasabach to the Ground Water Section of NJ DEP; 8/24/79. [Performance Standards].	16
38.	Memo on a 3000 gallon triethylene glycol spill, from Robert Runyon, NJ DEP to Spill File, 4/24/76. [Background].	12
39.	Review (critique) of PAS treatability study by Hydroqual, Inc., by O. Karl Scheible, performed for Converse Consultants. 8/16/83 [Engineering/Design].	52
40.	Performance standards applicable to a NJ DEP permit for groundwater decontamination of C.P.S./Madison, memo from Richard Dalton and Haig Kasabach to Director Gaston, 5/23/83. (Note: outlines a montioring protocol to be included in the remedial alternative-designed to judge effectiveness in terms of contaminant containment and removal). [Performance Standards].	44
41.	Update on C.P.S./Madison project, memo from Len Romino and Anthony Farro, HSMA to Dr. Marman Sadat, Administrator, HSMA; 1/31/83. [Background].	37
42.	Annotated map of piezometric levels with barely-legible notes on what chemicals have been found over time at what places. Undated. 1982? [Data/Results].	36
43.	Report of investigation of sources of pollution to Perth Amboy Well Fields, from Joseph Mikulka, NJ DEP, Div. Water Resources to Township of Madison, Borough of Sayreville, 5/11/73. [Background].	2
44.	Court Decision, City of Perth Amboy v. C.P.S./Madison and State of NJ vs. CPS, Superior Ct. of NJ, Docket No. L-28115-76; 7/31/81. [Legal].	27

APPENDIX A1

Project Document Summary

Title or Description/Author/Date

Document Control Number		Chronologic Sequence No
45.	CPS Well Sampling, Wells 6V and 6S, Sampled 6/8/81; NJ DEP Memo. Very high: carbon tet.; methylene chloride; toluene; 2,4-dihlorophenol, p-chloro-m-cvesol, and (base/neutrals); acemaphthalene, dimethyl phthalate (analytical problems?); Sampled 6/8/81, Memo dated 6/12/81. [Data/Results].	25
46.	Proposed monitoring program and performance standards for both operational and terminal (i.e., the point at which remedial actions are complete) phases of remedial action for C.P.S./Madison Industries, Wehran Engineering; 6/8/84 [Performance Standards].	74
47.	Results of Pricketts Pond Sediment Sampling - NJ DEP analysis of split samples from Converse study (Doc. No. 56). Includes both EP Toxicity concentrations and total concentrations of metals in samples. Sampled 3/8/84. Includes both metals and VO concentrations. Report submitted 4/13/84. [Data/Results].	65
48.	Well sampling protocols. Memo from Harvey to Maack, NJ DEP. Observing Converse sampling of 5/4/83 and 5/5/83. Comments on filtering of Samples, and indications of V. high contamination in BSL-12. (Note: T=27°C) 6/27/83. [Methods; Data/Results].	47
49.	Well sampling results, NJ DEP, Metals, 5/4/83. Incl. Wells P.A.-A, WCC-9N, WCC-9S, WCC-14, BSL-10, WCC-15W, PA-B, WCC-11N, WCC-15E, WCC-13, WCC-16, WCC-11C, WCC-11S; Sampled 5/4/83; Report submitted 5/26/83. [Data/Results].	43
50.	Same as Doc. No. 40	44
51.	Diagram of Converse Consultants Test Well and drawdown and recovery well data for Wells T-1, M-1, G&M, M-3 at Q=150 gpm. Undated. 1984? [Engineering/Results].	75

Document Control Number	Title or Description/Author/Date	Chronologic Sequence No
52.	Request from NJ DEP to US EPA to execute Superfund Cooperative Agreement for C.P.S./Madison. M.M Sadat to C. Simon 6/29/83 [Legal/Contractual].	48
53.	Request for additions to scope of work to finalize remedial plans for C.P.S./Madison; from Honachefsky & Dalton to Ron Senna, Div. Waste Management 7/11/83. [Engineering/Design].	49
54.	Well Sampling, C.P.S./Madison. Results of high-density sampling of CPS monitoring wells installed June 1981. Heavy metals and VO analysis. Samples collected 3/24/81. Memo from Maack & Tomasiello to Mumman, NJ DEP; 4/14/81. [Data/Results].	22
55.	Proposed alternate plan for stream diversion and grade; Wehran Engineering; 8/4/83. [Engineering].	50
56.	EP Toxicity Test Data, Pricketts Pond, Converse Consultants. Samples were split with NJ DEP (Doc. No. 47). Sampled 3/9/84. Includes Cd, Cu, Pb, Zn extractions; Report date 4/10/83. [Data/Results].	66
57.	News story on C.P.S./Madison well tampering; by R. G. Seidenstein; Star-Ledger, 5/24/84. [Background].	71
58.	News story on C.P.S./Madison well tampering, by Tom Damm, The News-Tribune, Woodbridge, NJ 5/24/84. [Background].	72
59.	Performance standards for removal of volatile organics. From Paul Harvey to NJ DEP STaff. 12/6/83. [Performance Standards].	61
60.	News story on indictments for dumping toxic chemicals - Incomplete, no date. Note: Indictment handed down in December, 1983. [Background].	62

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Document Control Number		Chronologic Sequence No
61.	Two telephone conversations between Paul Harvey, NJ DEP and (1) Bob Mutch - Wehran: Performance standards that C.P.S./Madison would have to accept before the modified clean-up plan could be agreed upon, and (2) with Charlie Robinson, AdTek Engineering - Re: Sediment sampling in Tennants Pond to determine if the 40,000 yd^3 of iron sludge in the pond contains other heavy metals. Both calls: 3/5/84. [Performance/Background].	64
62.	Maximum allowable concentrations of contaminants in groundwater below C.P.S./Madison. Memo from Paul Harvey to Ron Heksch (Deputy Attorney General) through McCann, Mummar, Maack, NJ DEP; 6/6/84. [Performance Standards].	73
63.	In-Depth critique of Wehran remedial action plan. Memo from C. Hunnewell, Geologist/Water Supply to Haig Kasabach, Dept. State Geologist, NJGS. Includes references to other documents; 11/21/83. [Engineering/Design].	60
64.	Florio Raps Cleanup Effort; News story in News Tribune, Woodbridge, NJ, 11/1/83. [Background].	59
65.	Relocation of Pricketts Creek, Memo from John O'Dowd, Bureau Chief, Bureau of Flood Plain Managment to John Gaston, Director, Div. Water Res. Technical review and Bureau preferences for rerouting Pricketts Brook; 10/25/83. [Engineering].	58
66.	Wehran computer model assumptions; Letter requesting information on input values used; From Jeff Hoffman, Senior Geologist, NJGS, to Bill Soukup, Wehran 10/7/83. [Engineering/Design].	56
67.	Two Memos: Review of Wehran Computer Model by Jeff Hoffman (to Kasabach) (10/14/83) and:	57

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Project Document Summary
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Document Control Number	Title or Description/Author/Date	Chronologic Sequence No
	Comments on Hoffman review plus pond sediment sampling protocol (apparently by John Trella), around 10/14/83. [Engineering/Design; Performance Standards].	
68.	Proposed groundwater discharges to MCUA. Letter from A.A. Lach, MCUA, to Ken Goldstein, NJ DEP, stating that based on treatability studies MCUA cannot accept discharge; 8/22/83. [Engineering/Design].	54
69.	Cover letter accompanying lab analysis sent to Blanche Hoffman of the Old Bridge Environmental Commission from Paul Harvey; 8/18/83. [Background].	53
70.	Volatile Organic Priority Pollutants in Sediments of Prickett's Pond. Report by Wehran; 4/84. [Results/Data].	70
71.	Letter from C.P.S/Madison counsel Rodburg to Honachefsky concerning monitoring wells; 10/20/75. [Background].	9
72.	Letter from C.P.S./Madison counsel Michael Rodburg to Honachefsky concerning the definition of groundwater and potential hazards/responsibilities for monitoring; 10/31/75. [Background].	10
73.	Historical summary of NJ DEP enforcement actions concerning C.P.S./Madision Industries, from Honachefsky to Frank Holloway (of Madison). Covers actions between 3/17/71 and 5/15/75; 8/4/75. [Background].	8
74.	Applications for Well Permits, C.P.S./Madison Industries; 7/16/75. [Engineering].	5
75.	Velocity of groundwater in Old Bridge Formation; memo from Kasabach to Honachefskey, NJ DEP; 2/6/76. [Engineering].	11

Document Control Number	Title or Description/Author/Date	Chronologic Sequence No
76.	Analysis of purgeable organics in wells for the Runyon Watershed. Sampled 12/12/78 to 12/13/78. From Francis Brezinski, US EPA Lab Director to Edward Post, NJ DEP; 1/15/79. [Results/Data].	15
77.	Lab analysis from C.P.S./Madison Industry wells; 5/17/77. [Results/Data].	13

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C.P.S./Madison Document Chronology

Chronologic Sequence Number	Date	Document File Number	Document[a] Type
1	3/14/51 - 7/1/55[c]	26	WP
2	5/11/73	43	D/R; B/H
3	3/73	15	MR; D/R
4	7/25/72 - 5/23/75[c]	23	WP
5	7/16/75	74	WP
6	7/27/75	24	WP
7	7/75	34	E/M/D
8	8/4/75	73	B/H; L/C
9	10/20/75	71	B/H
10	10/31/75	72	B/H
11	2/6/76	75	E/M/D
12	4/24/76	38	B/H
13	5/17/77	77	D/R
14	11/28/78	25	D/R
15	12/12/78 (1/15/79)[d]	76	D/R
16	8/24/79	37	PS
17	8/80	1	MR; E/M/D; D/R
18	11/26/80	5	E/M/D
19	1980[b]	12	D/R
20	1980[b]	13	D/R
21	2/25/81	31	E/M/D
22	3/24/81 (4/14)[d]	54	D/R
23	5/22/81	6	D/R
24	6/5/81	7	D/R
25	6/12/81	45	D/R
26	7/10/81	9	B/H
27	7/31/81	44	L/C
28	10/16/81	21	L/C
29	11/10/81	8	L/C
30	1981[b]	3	E/M/D
31	1981[b]	4	E/M/D
32	3/11/82 (9/24)[d]	36	D/R
33	3/24/82	27	D/R
34	4/7/82	10	D/R; E/M/D
35	9/1/82	32	D/R
36	1982?	42	D/R
37	1/31/83	41	B/H
38	2/7/83	29	D/R
39	2/9/83	28	D/R
40	2/22/83	33	E/M/D
41	3/3/83	35	B/H; L
42	5/3/83	18	MR; E/M/D
43	5/4/83 (5/26)	49	D/R
44	5/23/83	50 and 40	PS
45	5/83	16	MR; E/M/D; D/R
46	6/21/83	19	MR; E/M/D

APPENDIX A2
C.P.S./Madison Document Chronology

Chronologic Sequence Number	Date	Document File Number	Document[a] Type
47	6/27/83	48	D/R; E/M/D
48	6/29/83	52	L/C
49	7/11/83	53	E/M/D
50	8/4/83	55	E/M/D
51	8/16/83	30	E/M/D
52	8/16/83	39	E/M/D
53	8/18/83	69	B/H
54	8/22/83	68	E/M/D
55	9/83	17	MR; E/M/D; D/R
56	10/7/83	66	E/M/D
57	10/14/83	67	E/M/D; PS
58	10/25/83	65	E/M/D
59	11/1/83	64	B/H
60	11/21/83	63	E/M/D
61	12/6/83	60	PS
62	12/83	59	B/H; L/C
63	2/3/84	22	B/H; L/C
64	3/5/84	61	PS; B/H
65	3/8/84 (4/13)[d]	47	D/R
66	3/19/84 (4/10)[d]	56	D/R
67	3/28/84	20	E/M/D
68	4/24/84	11	E/M/D
69	4/84	2	MR; D/R
70	4/84	70	MR; E/M/D; D/R
71	5/24/84	57	B/H
72	5/24/84	58	B/H
73	6/6/84	62	PS
74	6/8/84	46	PS
75	1984	51	E/M/D

a. MR = Major Report; E/M/D = Engineering/Methods/Design; D/R = Data/Results; L/C = Legal/Contractual; B/H = Background/Historical; PS = Performance Standard; WP = Well Permits

b. Document undated, year assigned is an estimate.

c. Information applies to the time interval shown.

d. Sampling report. First date is sample collection date, second is report issue date.

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APPENDIX B

ADDITIONAL REFERENCES

Appendix B
ADDITIONAL REFERENCES

Stankowski, S.J. Magnitude and Frequency of Floods in New Jersey with Effects of Urbanization. U.S. Geological Survey Special Report 38, 1974.

Interim Soil Survey of Middlesex County, New Jersey. Soil Conservation Service, U.S. Department of Agriculture, 1978.

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APPENDIX C

C.1 DESCRIPTION OF SOILS IN THE PRICKETTS BROOK WATERSHED
C.2 INDEX TO MAP UNITS

Appendix C.1
DESCRIPTION OF SOILS IN THE PRICKETTS BROOK WATERSHED

The watershed has two distinct zones in terms of soil development. The upgradient zone of the watershed is characterized by moderately sloping sandy loam soils, extensive sand and gravel deposits (many of which have been mined), and considerable urban development. Individual soil mapping units are relatively small, mainly because of the frequent changes in slope. Soil types include the Woodstown sandy loam having a clayey substratum in areas that are nearly level (0 to 2 percent slope) to gently sloping (2 to 5 percent), and the Sassafras gravelly sandy loam in areas that are strongly sloping (5 to 10 percent) to moderately steep (10 to 15 percent). The Sassafras is moderately erodible (K=0.28) and has a moderate runoff potential (Hydrologic Soil Group B). The Woodstown has the same erodibility and runoff potential, but has a lower permeability in the substratum and has a higher seasonal high water table.

The downgradient zone is arbitrarily defined as the area that includes the wetland that extends to the east of CPS/Madison and the remaining downgradient area. It encompasses about 0.6 square miles. The downgradient zone is nearly level to gently sloping. Soils on the slopes and ridge tops in the downgradient zone are dominantly the Klej loamy sand and the Hammonton loamy sand. These soils are similar except that the Klej has a slightly coarser subsoil and higher permeability. Both soils have a seasonal high water table between 1-1/2 to 4 feet below the ground surface. The Hammonton is more erodible (K=.28) than the Klej (K=.17), and has a higher runoff potential (Group B) than the Klej (Group A). The Hammonton has a high susceptibility to frost heave.

The eastern border of Pricketts Pond is mapped as the Evesboro sand. This soil series is a deep sand with a low runoff potential (Group A), low susceptibility to erosion (K=.17), and has a seasonal high water table deeper than 5 feet below the ground surface.

Soils in the low-lying level areas of the downgradient zone are subject to flooding year round. They typically have organic surface soil horizons with sandy subsoils. Because they occupy areas of very low relief, they are not susceptible to erosion by runoff. Soils of this type tend to be susceptible to wind erosion and subsidence when drained, however. Because they are constantly wet, they have a high runoff potential (Group D). The Manahawkin Muck and unclassified Humaquepts (wet soils with an organic surface and poorly developed horizonation) occupy these low-lying positions. A copy of the interim soil survey map sheets that include the Pricketts Brook watershed are shown in Figure C.1. The mapping units shown on the map can be identified using the Index to Map Units that follows.

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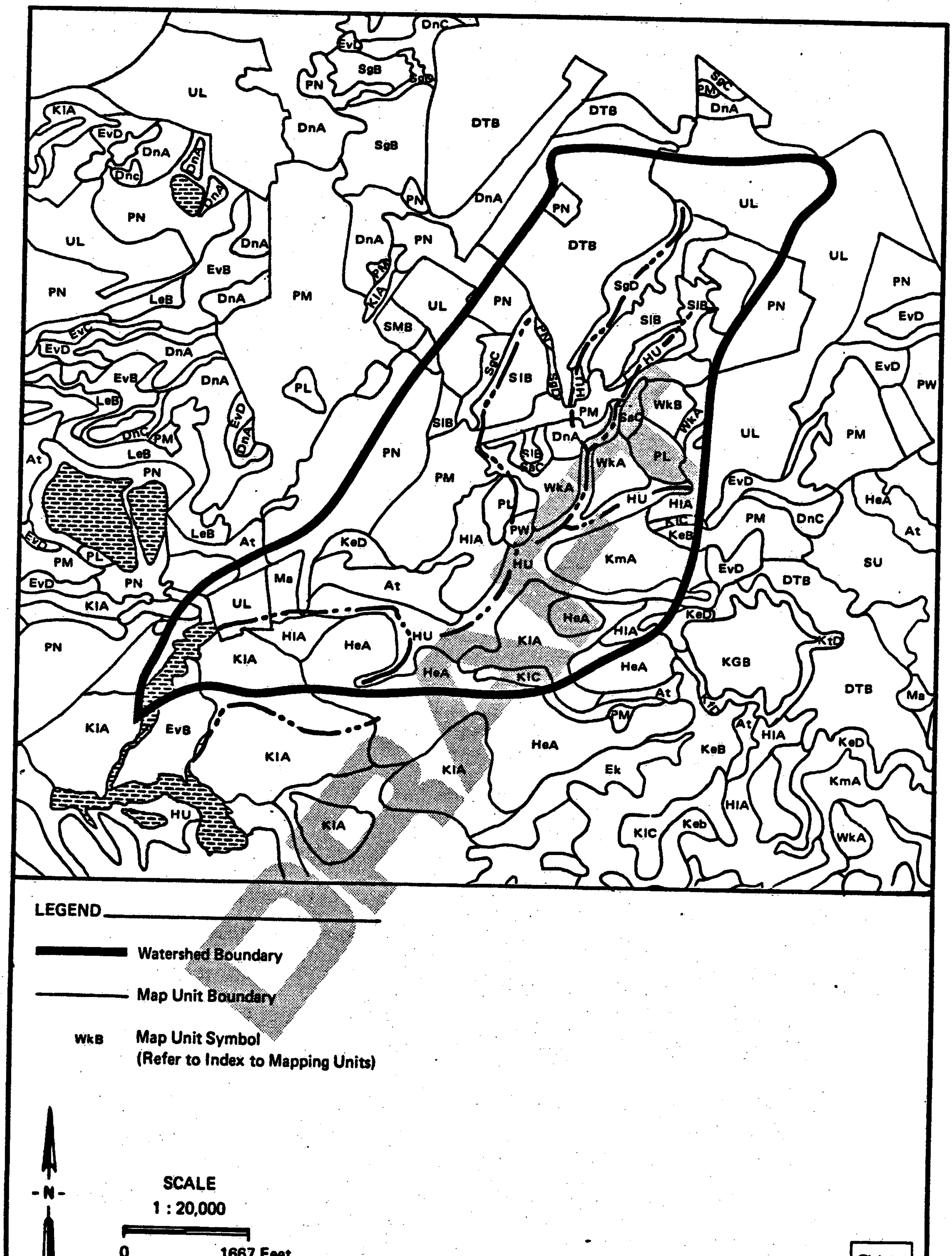

Figure C.1
Soil Map of Pricketts Pond Watershed

APPENDIX C2
INDEX TO MAP UNITS

INDEX TO MAP UNITS

INDEX TO MAP UNITS

INDEX TO MAP UNITS

INDEX TO MAP UNITS